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Karyomorphological Studies in the Family Pinaceae*

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Introduction

The Pinaceae is the largest family in the gymnosperms and is represented by ten genera and over 200 species (Sporne 1965). All members of the family are concentrated in the northern hemisphere. Fossils of the extant genera of the Pinaceae have been discovered in late Cretaceous to the Tertiary deposits and the change of distribution of the genera was understood relatively by certain evidences of fossil records (Florin 1963, Miller 1976, 1977). At present species belonging to *Pinus*, *Picea*, *Abies* and *Larix* grow widely and form ecologically and economically important forests in the northern hemisphere.

Much general information regarding taxonomy, phylogeny, pollination ecology, immunology, chemistry, cytology and so on in the Pinaceae has been summarized as follows: In classification Pilger (1926) divided the Pinaceae into two subfamilies, Abietoideae and Pinoideae, and Pilger & Melchior (1954) redivided it into three subfamilies, Abietoideae (*Abies*, *Cathaya*, *Keteleeria*, *Picea*, *Pseudotsuga* and *Tsuga*), Laricoideae (*Cedrus*, *Larix* and *Pseudolarix*) and Pinoideae (*Pinus*), while the other taxonomists such as Rehder (1940) did not subdivided the family. Flous (1936) proposed phylogenetic relations between the closely related genera such as *Pinus* and *Picea*, *Pseudolarix* and *Keteleeria*, *Larix* and *Pseudotsuga*, and *Cedrus* and *Abies* on the basis of morphological characters and fossil evidences. Doyle (1945) investigated pollination mechanisms in the Pinaceae and distinguished two lines, one comprising of *Pinus*, *Larix* and *Pseudotsuga* and the other *Pseudolarix*?, *Abies*, *Cedrus* and *Tsuga*. Immunological analysis (Prager *et al.* 1976) and chemical analysis of organic substance (Niemann & Van Genderen 1980) indicated similarity between certain genera, which were changed ranks to respective subfamilies by Pilger & Melchior (1954). The relationships among the genera of the Pinaceae, however, have been scarcely described.

Cytological approach is sometimes useful to reveal the phylogenetic relationships of organisms. The study on chromosomes of the Pinaceae began in the early twentieth century. In the early studies the chromosome numbers were examined accompanying with

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anatomical investigation on fertilization and embryogenesis by the paraffin sectioning method. However, chromosome morphology had been examined deficiently since chromosomes of the Pinaceae are relatively large in size and many in number. Sax & Sax (1933) had studied the chromosome number and morphology in early development of endosperm (haploid tissue) of 53 species belonging to 16 genera of the conifer by the squash method and their work was pioneering and important contribution in the cytology of the gymnosperms. Since Mehra & Khoshoo (1956) introduced a pretreatment with chemical substances or cold shock to contraction of chromosomes and observed chromosome morphology in root tips of many coniferous species, many investigations have been done in this field (summarized by Khoshoo 1961, Mehra 1968). It is generally accepted that the genera of the Pinaceae possess the common basic chromosome number of x=12 excepting for *Pseudotsuga menziesii* (n=13) and *Pseudolarix kaempferi* (n=22), and that the karyotype at metaphase is stable in each genus.

It is difficult to compare karyotypes obtained with different techniques by different authors. Therefore, it could be necessary to reveal the phylogenetic relationships among the genera and the species in the Pinaceae with respect to chromosome morphology observed by same cytological technique.

In the present paper 83 taxa of nine genera in the Pinaceae were dealt with karyomorphology at interphase, mitotic prophase and metaphase to reveal their interrelationships.

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Materials and Methods

1. Materials

Trees and seeds of 76 species and seven varieties belonging to nine genera (Table 1) in the Pinaceae were investigated karyomorphologically. The locality or source of each taxon used is shown in Table 1. Identification of the plants growing in natural stands, experimental forests and botanical gardens followed Ohwi (1965) for Japanese species, Rehder (1940) for North American species and Den Ouden & Boom (1965) for other continental species. The species names of the seeds supplied from certain foreign countries were determined by their suppliers. Taxonomic treatment of the genera and the taxa used was essentially followed Pilger & Melchior (1954) and that of species in *Pinus* followed Critchfield & Little (1966). Scientific and Japanese names of the species native to Japan followed Ohwi (1965).

Table 1. Locarity and chromosome nunber of 83 taxa (76 species and 7 varieties) of nine genera in Pinaceae examined

Taxon	No. plants observed	Chromosome number(2n)	Locarity (Source)
Abies concolor	18	24	Colorado, U.S.A. (C.F.S.S.B.)
A. lasiocarpa	20	24	Monshee Mountains, British Columbia, Canada (C.F.S.S.B.)
A. ernestii	10	24	Nanjing Forestry University, Nanjing, China
A. veitchii	15	24	Minamiazumi, Nagano Pref., Japan (F.F.P.R.I.)
var. sikokiana	5	24	Mt. Ishizuti, Ehime Pref., Japan
A. sachalinensis	12	24	Tomae, Hokkaido, Japan (F.F.P.R.I.)
	16	24	Hiyama, Atusawabe, Hokkaido, Japan (Hokkaido Branch, For. & For. Prod. Res. Inst., Hokkaido)
A. firma	3	24	Yuki T., Hiroshima Pref., Japan
	6	24	Mt. Higasiakaishi, Doi T., Ehime Pref., Japan
	2	24	Mt. Ishizuti, Omogo V., Ehime Pref., Japan
A. homolepis	5	24	Mt. Higasiakaishi, Doi T., Ehime Pref., Japan
	3	24	Mt. Ishizuti, Omogo V., Ehime Pref., Japan
	15	24	Kiso, Nagano Pref., Japan (F.F.P.R.I.)
A. mariesii	40	24	Hatimantai,Iwate Pref., Japan (Touhoku Branch, For. & For. Pro. Res. Inst., Morioka C., Aomori Pref.)
A. balsamea	20	24	P.F.E.S., Ontario, Canada (C.F.S.S.B.)
Keteleeria davidiana	50	24	Kyoto Pref. Botanical Garden, Kyoto Pref., Japan
	1	24	Aritaki Arbor., Koshigaya C., Saitama Pref., Japan
	1	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
Pseudotsuga menziesii	20	26	Thaddeus Lake, British Columbia, Canada (C.F.S.S.B.)
	5	26	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
	2	26	Kobe Municipal Arbor., Kobe C., Hyogo Pref., Japan
	3	26	Univ. Toronto, Lab. Garden, G. Lendon, Mall., Canada
	5	26	Hortus Botanicus Centralis Academiae Scientiarm UCR-SSR, Kiev U.R.S.S.
	6	26	CIVICO ORTO Botanico Piazza Hortis, Trieste, Italy

Table 1. (continued)

Pseudotsuga japonica	12	24	Mt. Yasudagawa, Umaji V., Kōchi Pref., Japan
	1	24	Kobe Municipal Arbor., Kobe C., Hyogo Pref., Japan
Tsuga canadensis	5	24	Highlands Biological Station, Highland, N. C., U.S.A.
	10	24	Cormac, Ontario, Canada (C.F.S.S.B.)
T. heterophylla	12	24	Queen Charlotte Islands, B. C. Canada (C.F.S.S.B.)
	5	24	commercial source (Clyde Robin Seed Co. Inc., Calif. U.S.A.)
T. caroliniana	5	24	U.S.A. (C.F.S.S.B.)
T. sieboldii	7	24	Mt. Higashiakaishi, Doi T., Ehime Pref., Japan
	10	24	Omogo-kei, Omogo V. Ehime Pref., Japan
	3	24	Mt. Kanmuri, Hiroshima Pref., Japan
T. diversifolia	9	24	Mt. Higashiakaishi, Doi T., Ehime Pref., Japan
T. chinensis	14	24	Nanjing Forestry University, Nanjing, China
Picea abies	1	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
	15	24	Scotland (F.F.P.R.I.)
	20	24	commercial source (Yamatoya Co., Tokyo.)
P. orientalis	15	24	commercial source (Yamatoya Co., Tokyo.)
P. glauca	20	24	P.F.E.S., Ontario, Canada (C.F.S.S.B.)
P. mariana	20	24	P.F.E.S., Ontario, Canada (C.F.S.S.B.)
	5	24	Indian Bay, N. F., Canada (C.F.S.S.B.)
P. rubens	20	24	Green river, N. B., Canada (C.F.S.S.B.)
	9	24	Timber lake, N. S., Canada (C.F.S.S.B.)
P. engelmannii	15	24	Highwood Summit, Alta., Canada (C.F.S.S.B.)
	6	24	Botanical Garden, Univ. B. C., Canada
P. pungens	20	24	San Isabel National Forest, Colorado, U.S.A. (C.F.S.S.B.)
	2	24	Colorado, U.S.A.
P. bicolor	4	24	Minamituru, Yamanasi Pref., Japan (F.F.P.R.I.)
	16	24	Yamanasi Pref., Japan(C.F.S.S.B.)
P. glehnii	20	24	Kamikawa, Hokkaido, Japan (F.F.P.R.I.)
	20	24	Mt. Daisetu, Asahikawa, Hokkaido, Japan
	12	24	Souunkyou, Kawakami, Hokkaido, Japan (F.F.P.R.I.)
P. koyamae	20	24	Suwa, Nagano Pref., Japan (F.F.P.R.I.)
P. polita	1	24	Kamigamo Exp. Sta., Kyoto Univ. Forest, Kyoto Pref., Japan
	20	24	Mt. Fuji, Yamanashi Pref., Japan
P. asperata	12	24	Nanjing Forestry University, Nanjing, China
P. smithiana	20	24	commercial source (Yamatoya Co., Tokyo)
P. omorika	15	24	West Germany (C.F.S.S.B.)
	10	24	commercial source (Clyde Robin Seed Co. Inc., Calif. U.S.A.)
P. sitchensis	20	24	Big Gualicum River, B. C., Canada (C.F.S.S.B.)
	5	24	Botanical Garden, Univ. B. C., Canada
P. jezoensis	20	24	Tokoro, Hokkaido, Japan (F.F.P.R.I.)
	5	24	Asyoro, Hokkaido, Japan
	10	24	Monbetsu, Hokkaido, Japan
	20	24	Oketo, Tunero, Hokkaido, Japan
var. *hondoensis*	20	24	Kiso, Nagano Pref., Japan (F.F.P.R.I.)
	20	24	Fujiyosida, Yamanashi Pref., Japan (F.F.P.R.I.)

Table 1. (continued)

Pseudolarix kaempferi	5	44	Ohji Institute for Forest Tree Improvement, Kameyama, Mie Pref., Japan
	1	44	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
	1	44	Kobe Municipal Arbor., Kobe C., Hyogo Pref., Japan
Larix potaninii	13	24	Shiao-Jin, Szechuan Prov., China (C.F.S.S.B.)
	11	24	Nanjing Forestry University, Nanjing, China
L. occidentalis	42	24	Flathead valley, B.C., Canada (C.F.S.S.B.)
L. leptolepis	12	24	Ngano Pref., Japan (C.F.S.S.B.)
	13	24	Minamituru, Yamanasi Pref., Japan (F.F.P.R.I.)
	15	24	Nikkou C., Totigi Pref., Japan (F.F.P.R.I.)
	35	24	Tadesina, Nagano Pref., Japan
L. gmelinii	20	24	Yakutskaya, U.S.S.R. (C.F.S.S.B.)
	20	24	Kirin, China (C.F.S.S.B.)
var. *japonica*	20	24	Tartu, Estonian U.S.S.R. (C.F.S.S.B.)
var. *principis-rupprechtii*	10	24	Da-Tung, San-shi, China (C.F.S.S.B.)
	10	24	Najing Forestry University, Nanjing, China
L. decidua	15	24	Sabinov, Czechoslovakia (C.F.S.S.B.)
	10	24	Jagersbrog, Denmark (C.F.S.S.B.)
	10	24	Europ. Bundesstr, Germany (C.F.S.S.B.)
	10	24	Chocen, Czechoslovakia (C.F.S.S.B.)
L. laricina	30	24	Trecesson, Canada (C.F.S.S.B.)
	30	24	Lake Chertsey, Canada (C.F.S.S.B.)
Cedrus deodara	2	24	Hiroshima Pref. Expt. For. Sta., Miyoshi, Hiroshima Pref., Japan
	3	24	Horinouti Park., Matsuyama, Ehime Pref., Japan
	5	24	Thandiani, Pakistan (C.F.S.S.B.)
Pinus strobus	4	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
	2	24	Kansai For. Tree Breed. Inst., Okayama Pref., Japan
P. monticola	3	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
P. peuce	5	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
P. parviflora	5	24	Kamiukena, Ehime Pref., Japan
	8	24	Kiso, Nagano Pref., Japan
	10	24	Mt. Higashiakaishi, Doi T., Ehime Pref., Japan
	10	24	Fujiyoshida C., Yamanashi Pref., Japan
P. edulis	20	24	Coconino, Arizona, U.S.A. (U.S.F.T.S.C.)
P. bungeana	5	24	Hortus Botanicus Pekinensis, Inst. Bot. Acad. Sinicae, Beijing, China
	1	24	Kansai For. Tree Breed. Inst., Okayama Pref., Japan
P. aristata	5	24	commercial source (Clyde Robin Seed Co. Inc.,Calif. U.S.A.)
P. canariensis	5	24	commercial source (Clyde Robin Seed Co. Inc.,Calif. U.S.A.)
P. roxburghii	10	24	Gov. India For. Res. Inst. Coll., Dehr Dun, India
P. pinea	5	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
P. resinosa	30	24	Mac Diarmid, Ont. Canada (C.F.S.S.B.)

Table 1. (continued)

Pinus nigra	5	24	Italy (F.F.P.R.I.)
	5	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
	10	24	CIVICO ORTO Botanico Piazza Hortis, Trieste, Italy
P. mugo	3	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
P. pinaster	4	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
P. stankewiczii	3	24	ORTO Botanico Pisano, Inst. Bot. Della Univ., Pisa, Italy
P. brutia	5	24	ORTO Botanico Pisano, Inst. Bot. Della Univ., Pisa, Italy
	5	24	CIVICO ORTO Botanico Piazza Hortis, Trieste, Italy
P. sylvestris	12	24	England (F.F.P.R.I.)
	3	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
P. densiflora	5	24	Kansai Forest tree breeding Institute, Okayama Pref., Japan
	20	24	Hiroshima Pref. For. Sta., Miyoshi, Hiroshima Pref., Japan
	20	24	Mt. Tagami, Iyo C., Ehime Pref., Japan
	10	24	Siwa, Iwate Pref., Japan
	10	24	Miyagi, Miyagi Pref., Japan (F.F.P.R.I.)
	10	24	Minamikaifu, Ohita Pref., Japan (F.F.P.R.I.)
	10	24	Futaba, Fukusima Pref., Japan (F.F.P.R.I.)
	10	24	Kitasaku, Nagano Pref., Japan (F.F.P.R.I.)
	10	24	Iwate, Iwate Pref., Japan (F.F.P.R.I.)
	10	24	HigashiIwai, Iwate Pref., Japan (F.F.P.R.I.)
	10	24	Iwami, Tottori Pref., Japan (F.F.P.R.I.)
	10	24	Katuta, Okayama Pref., Japan (F.F.P.R.I.)
	10	24	Tosiro, Miyazaki Pref., Japan(F.F.P.R.I.)
	10	24	Hata, Kouchi Pref., Japan (F.F.P.R.I.)
	10	24	Fujiyosida C., Yamanashi Pref., Japan (F.F.P.R.I.)
P. thunbergii	10	24	Komatsu C., Kanazawa Pref., Japan (F.F.P.R.I.)
	10	24	Inasa, Shizuoka Pref., Japan, Japan
	10	24	Hinomisaki, Shimane Pref., Japan
P. luchuensis	30	24	Okinawa Pref. Exp. For. Sta., Nago C., Okinawa Pref., Japan
P. yunnanensis	10	24	Nanjing Forestry University, Nanjing, China
P. khasya	10	24	Thailand (F.F.P.R.I.)
	5	24	Nanjing Forestry University, Nanjing, China
P. taeda	10	24	Okayama C., Okayama Pref., Japan
	10	24	York, South Carolina, U.S.A. (U.S.F.T.S.C.)
	3	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
	10	24	Texas For. Serv. For. Genet. Lab. Coll. Sta., TX, U.S.A.
P. rigida	10	24	Okayama C. Okayama Pref., Japan (F.F.P.R.I.)
	10	24	Hardy, West Virginia, U.S.A. (U.S.F.T.S.C.)
P. serotina	20	24	Charleston, South Carolina, U.S.A. (U.S.F.T.S.C.)
P. pungens	10	24	Rabun, Georgia, U.S.A. (U.S.F.T.S.C.)
P. elliottii	13	24	Texas For. Serv. For. Genet. Lab., Coll. Sta., Tx, U.S.A.
	3	24	Ehime Pref. Green Center, Shigenobu T., Ehime Pref., Japan

Table 1. (continued)

Pinus caribaea			
var. *hondurensis*	50	24	Honduras (F.F.P.R.I.)
P. ponderosa	16	24	Falkland, B. C., Canada (C.F.S.S.B.)
P. jeffreyi	9	24	commercial source (Clyde Robin Seed Co. Inc., Calif. U.S.A.)
P. torreyana	5	24	commercial source (F. W. Schumacher Co., Mass. U.S.A.)
P. banksiana	6	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
P. contorta			
var. *contorta*	20	24	Richimond, B. C., Canada (C.F.S.S.B.)
var. *murrayana*	7	24	C.F.S.S.B.
P. virginiana	10	24	York, South Carolina, U.S.A. (U.S.F.T.S.C.)
	3	24	Kamigamo Exp. Stn. Kyoto Univ. Forest, Kyoto Pref., Japan
P. muricata	3	24	commercial source (Clyde Robin Seed Co. Inc., Calif. U.S.A.)
P. greggii	5	24	commercial source (Clyde Robin Seed Co. Inc., Calif. U.S.A.)

P.F.E.S.: Petawawa Forestry Experimental Station, Ontario, Canada
F.F.P.R.I.: Forest and Forest Products Reserch Institute, Tsukuba, Ibaraki, Japan
C.F.S.S.B.: Canadian Forest Service Seed Bank, P.F.E.S., Ontario, Canada
U.S.F.T.S.C.: United Forest Tree Seed Center, Forest Service, Georgia, U.S.A.

The actively growing root tips of many of the species used were collected from trees planted in pots during spring to summer. The seeds were soaked in freshly prepared 5% sodium hypochloride solution for 20 minutes to surface sterilization and then thoroughly washed twice with sterile distilled water for 20 minutes each. The seeds were, then, planted on moistened filter paper in petri dishes and incubated at a constant 23℃ in an incubator. The seeds germinated usually within 5 to 10 days after they were sown and then, their root tips were collected for cytological observation. Young leaves of the shoot apex of a few species were also collected. Live voucher specimens were maintained at the experimental garden of Faculty of Education, Ehime University and some voucher specimens were deposited in the herbarium of the Biological Institute.

2. Methods

The collected materials, root tips mostly and young leaves sometimes, were immersed in 0.002 M 8-hydroxyquinoline or 0.05% colchicine at room temperature (about 20℃) for pretreatment. Duration of pretreatment required 10–15 hours to adequate condensation for observation of chromosome morphology. Then, the materials were fixed in the modified Carnoy's solution (glacial acetic acid : chloroform : ethyl alcohol, 1 : 1 : 2) at 4℃ for overnight. The materials were hydrolyzed in the mixture of one part of 45% acetic acid and two parts of 1N HCl at 60℃ for 10–20 seconds and then transferred into ice-cooled 45% acetic acid. Under a binocular the materials were dissected longitudinally and then the

meristematic tissues were picked up onto glass slide by needle with flattened tip. The isolated meristematic tissues were stained with 2% aceto-orcein (Kanto Chemical Co., Tokyo) for 15–30 minutes. After staining the excess stain solution on the glass slide was removed by filter paper and then, new stain solution was added. The coverglass was put on the stained meristematic tissue on the glass slide and then cells were made scattered by gentle tapping on the coverglass with needle. After the preparation was incubated at room temperature for 5 minutes, the the coverglass was pressed firmly with filter paper to flatten the cell and remove excess aceto-orcein. If the chromosome preparation was found to be satisfactory, it was sealed with the 'VALAP' (mixture of two parts of vaseline, two parts of lanolin and one part of paraffin).

Observations were made on chromosomes not only at metaphase but also at interphase and prophase. The chromosomes at interphase or prophase appeared most frequently and their typical morphology were selected and observed in details. Karyotypes at interphase, and mitotic prophase and metaphase were expressed according to Tanaka's nomenclature system (1971, 1977). The classification of karyotypes at interphase followed Tanaka (1977); 1. the densely diffuse type, 2. the simple chromocenter type, 3. the complex chromocenter type, 4. the gradient type, 5. the rod-shaped prochromosome type, 6. the round prochromosome type and 7. the diffuse type. The classification of karyotypes at mitotic prophase followed Tanaka (1977); 1. the continuous type, 2. the interstitial type, 3. the gradient type, 4. the proximal type and 5. the tenuous type. The cells with the metaphase chromosomes which contracted at 2/3 in size and well scattered were chosen for observation. The figures of chromosomes at each stage were observed under a microscope equipped with optics of plan apo 100 × objective lens and taken photographs on minicopy film (Fuji Film Co., Tokyo) with a film plane magnification of 500 diameters. The negative films were enlarged 4.8 times on print papers to get a final magnification of 2400 diameters. The photographs of metaphase chromosomes were cut out individually. The separated chromosome-figures were tentatively arranged according to their length. The length of long and short arms of each chromosomes were measured using a divider and an accurately scale or a slide calipers and the location of secondary constriction were measured. Relative chromosome length, arm ratio (length of long arm / length of short arm), total length of chromosomes were calculated from measured chromosomal values. Finally, the chromosomes were rearranged on the basis of the chromosome length measured, position of centromere, and location of secondary constriction. The nomenclature system of Levan *et al.* (1964) for position of centromere was essentially used designation of individual chromosomes. A new class, median-submedian (msm type) that was created a final distinction between median and submedian type chromosomes (1.3–1.7 arm ratio) by Schlarbaum & Tsuchiya (1984) was also used. The lengths of chromosomes were divided into three types according to net length. Chromosomes with 10–15 μm in length, with 6–10 μm and under 5 μm were called here large, medium-sized and small, respectively. In some cases size was determined in consideration of degree of condensation of

chromosome arms and variation of length in chromosome complement.

On the basis of karyomorphological similarity in chromosomes at metaphase the karyotypes were divided into several types and the grouping was compared with the previous taxonomical and phylogenetic reports.

Results

1. *Abies concolor* Engelm., 2n=24, Table 2 and Fig. 1

Seeds collected in Colorado, U.S.A. (Table 1), seeds were germinated and their root tips were used for karyomorphological observation. The chromosome number was counted to be 2n=24 in all of 18 plants, which confirmed the previous count reported by Sax & Sax (1933).

The chromosomes at interphase formed about 20–30 darkly stained chromatin blocks. The blocks appeared to be spherical in shape. Some chromosomes formed many chromomeric granules and the others formed fibrous chromatin threads (Fig. 1A). Thus, morphology of the chromosomes at interphase is categorized to be the complex chromocenter type. Three to eight nucleoli were observed in each cell.

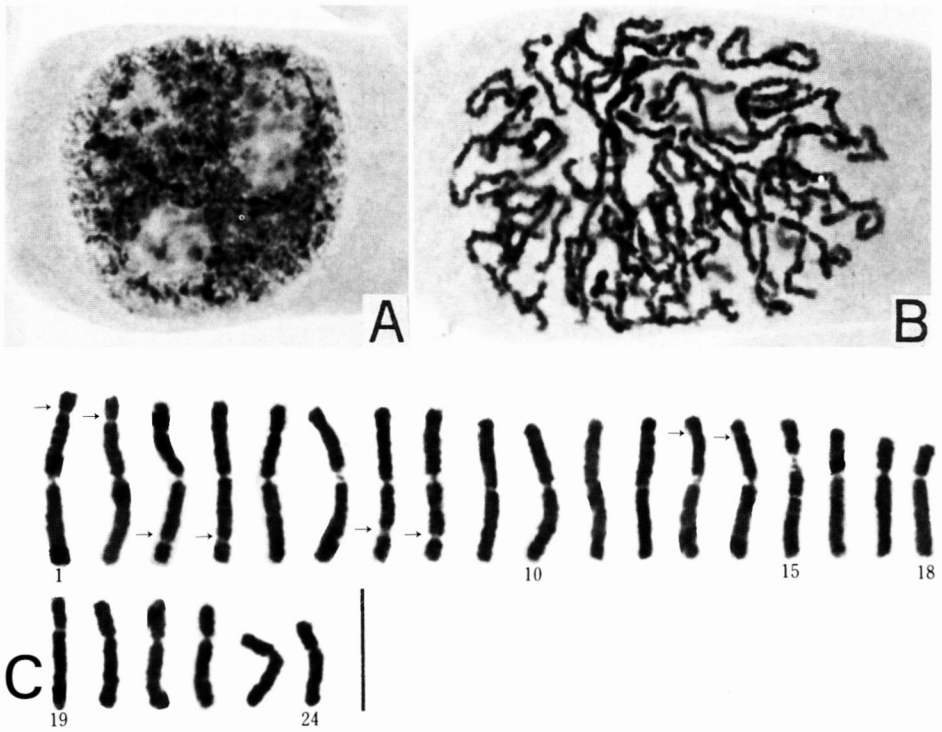

Fig. 1. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Abies concolor* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes of every set at mitotic prophase condensed homogeneously along a long axis. Difference in condensation was not observed among the segments and the chromosomes in similar diameter throughout the whole regions (Fig. 1B). Thus, morphology of prophase chromosomes is considered to be the continuous type.

The chromosomes at mitotic metaphase varied in length from 13.4–7.2 μm. Fourteen chromosomes (seven pairs) were larger than the other ten chromosomes (five pairs). The larger chromosomes were classified as large-sized and the smaller chromosomes were classified as medium-sized. In each of these two chromosome groups with respect to chromosome length the chromosomes gradually varied in length. They were observed to be the bimodal type in chromosome length (Table 2): The 14 larger chromosomes were metacentric and the others were submetacentric (Fig. 1C). These results of karyomorphological observation at mitotic metaphase are generally similar to those reported by Sax & Sax (1933).

Secondary constrictions were observed here for the first time. Four pairs of large metacentric chromosomes (the 1st, 2nd, 4th, 7th pairs) possessed secondary constrictions at interstitial regions on one of their arms.

2. *Abies lasiocarpa* (Hook.) Nutt., 2n=24, Fig. 2

The observation was made on the meristematic tissues of root tips of 20 seedlings

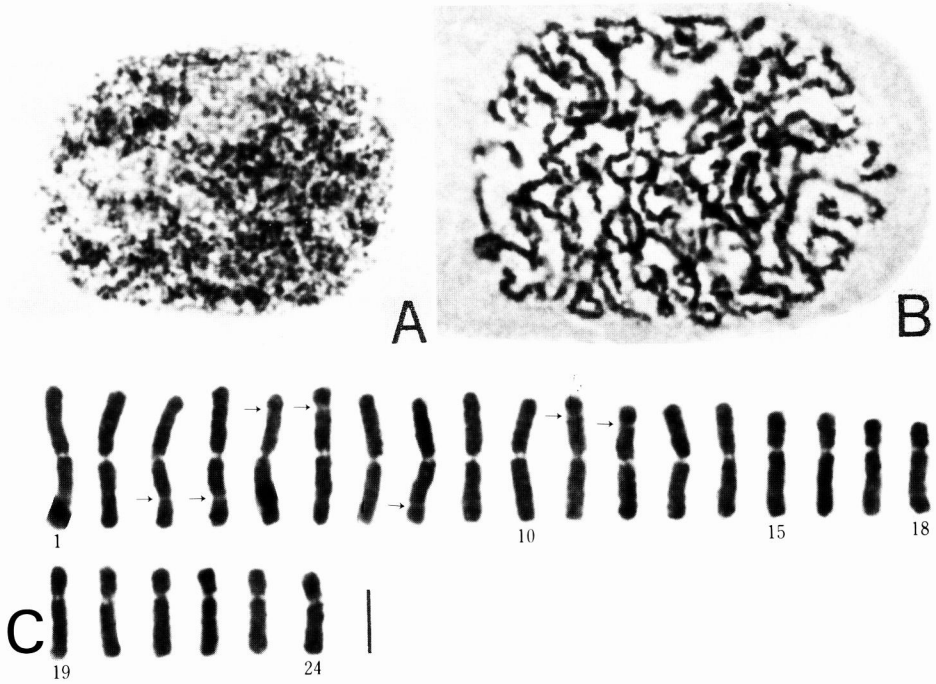

Fig. 2. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Abies lasiocarpa* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

established from the seeds collected in Monshee Mountains, British Columbia, Canada. The chromosome number was counted to be 2n=24 in all of the plants, which was identical to the previous count reported by Mergen & Burley (1964).

The chromosomes at interphase (Fig. 2A) and at mitotic prophase (Fig. 2B) were observed to be similar to those of *A. concolor*. Morphology of the chromosomes at interphase and prophase is categorized to be the complex chromocenter type and the continuous type, respectively.

The chromosomes of every set at mitotic metaphase varied in length from 11.7–6.8 μm. Seventeen chromosomes were clearly larger than the other ten chromosomes as observed in *A. concolor*. In each of these chromosomes group with respect to chromosome length the chromosomes gradually varied in length. They formed a bimodal karyotype in length: the 14 larger chromosomes were metacentric and the others were submetacentric (Fig. 2C). Thus, the karyotype at metaphase is generally similar to that reported by Mergen & Burley (1964). Four pairs of large metacentric chromosomes (the 2nd, 3rd, 4th, 6th pairs) possessed secondary constrictions at interstitial regions on one of their arms.

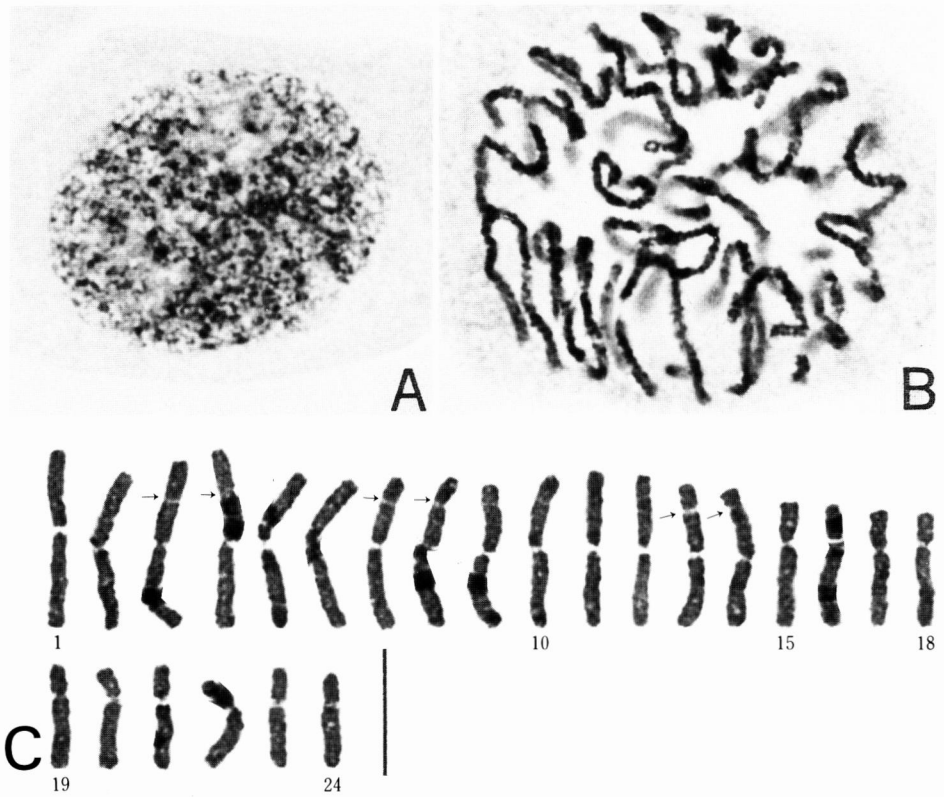

Fig. 3. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Abies ernestii* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

3. *Abies ernestii* Rehd., 2n=24, Fig. 3

The seeds obtained from the People's Republic of China (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number was 2n=24 counted here for the first time.

Morphology of the chromosomes at interphase (Fig. 3A) and at mitotic prophase (Fig. 3B) was similar to that observed in *A. concolor* and was, thus, categorized to be the complex chromocenter type and the continuous type, respectively.

The chromosomes of every set at mitotic metaphase varied in length from 14.8–7.7 μm. Seven pairs of chromosomes were large and five pairs were medium-sized. The chromosome complement showed a bimodal karyotype. In each of these chromosome group with respect to chromosome length the chromosome varied gradually in length. All large-sized chromosomes possessed the centromeres at their median positions while all medium-sized chromosomes possessed the centromeres at their submedian positions (Fig. 3C). The secondary constrictions frequently appeared at interstitial regions of one of arms on three pairs of large metacentric chromosomes (the 2nd, 4th, 7th pairs).

4. *Abies veitchii* Ldl., 2n=24, Fig. 4 (Japanese name : Shirabe)

The seeds collected in Nagano Pref., Japan were germinated and their root tips were used for cytological observation. The chromosome number was counted to be 2n=24 in all of the 15 seedlings studied, which confirmed the previous report by Sax & Sax (1933).

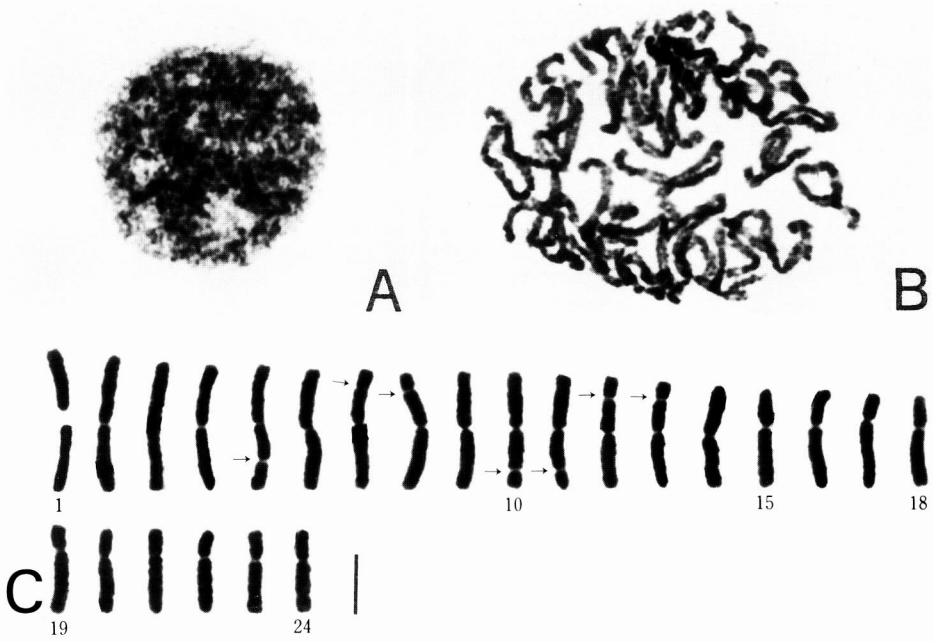

Fig. 4. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Abies veitchii* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

Morphology of the chromosomes at interphase (Fig. 4A) and at mitotic prophase (Fig. 4B) was similar to that observed in *A. concolor* and categorized to be the complex chromocenter type and the continuous type, respectively.

The chromosomes of every set at mitotic metaphase varied in length from 11.2–6.7 μm. Seven pairs of chromosomes were large-sized and five pairs were medium-sized. The complement formed a bimodal karyotype, of which chromosome each group showed gradual decrease in size from the largest to the shortest chromosomes. All large chromosomes possessed the centromeres at their median positions, while all medium-sized chromosomes possessed the centromeres at their submedian positions (Fig. 4C). Secondary constrictions were observed at interstitial regions of either long or short arms of seven chromosomes.

5. *Abies veitchii* var. *sikokiana* (Nakai) Kusaka, 2n=24, Fig. 5 (Japanese name : Shikoku-shirabe)

Five young trees were collected in Mt. Ishizuti, Ehime Pref., Japan and their root tips were investigated cytologically. The chromosome number of 2n=24 in five plants was recorded here for the first time.

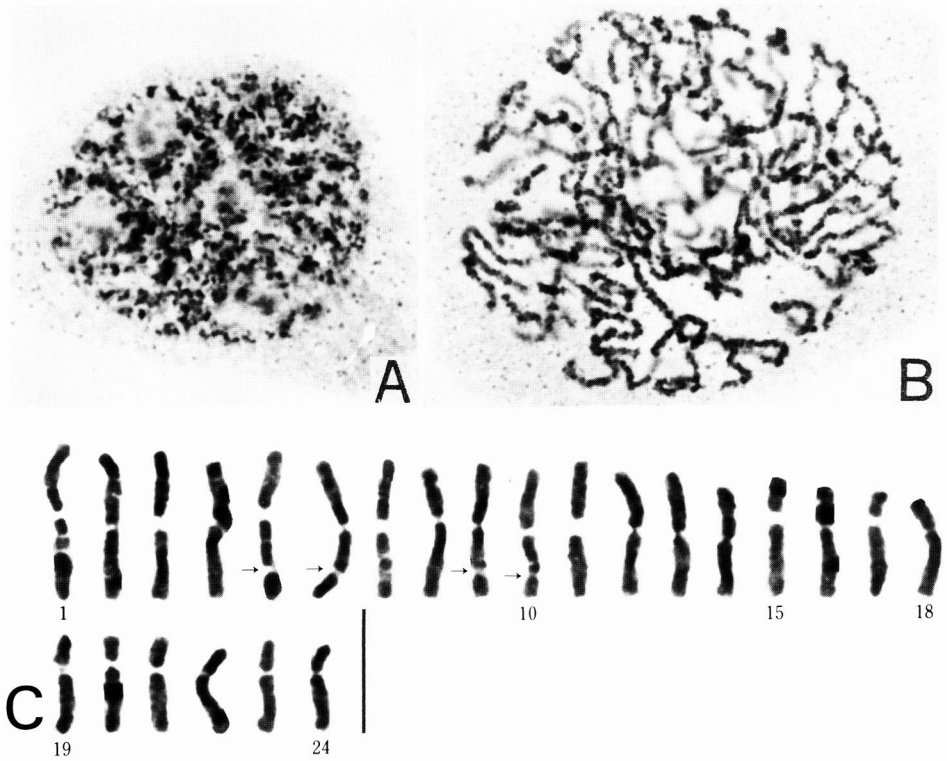

Fig. 5. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Abies veitchii* var. *sikokiana* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

Morphology of chromosomes at interphase (Fig. 5A) and at mitotic prophase (Fig. 5B) was observed to be similar to that observed in *A. veitchii* and was categorized to be the complex chromocenter type and the continuous type, respectively. Two to six nucleoli were observed in each nucleus.

The chromosomes of every set at mitotic metaphase varied in length from 12.1–7.3 μm. Seven pairs of chromosomes were larger than the other five pairs and formed the chromosome complement of a bimodal karyotype. All large-sized chromosomes possessed the centromeres at their median positions while all medium-sized chromosomes possessed the centromeres at their submedian positions (Fig. 5C). Secondary constrictions were observed at interstitial regions of one of arms of two pairs of chromosomes (the 3rd, 5th pairs).

6. *Abies sachalinensis* (F. Schmidt) Mast., 2n=24, Fig. 6 (Japanese name : Aka-todo-matsu)

The seeds collected at two localities of Hokkaido, Japan (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number was counted 2n=24 in the 28 plants examined, which confirmed the previous reports by Mergen & Lester (1961) and Price *et al.* (1973).

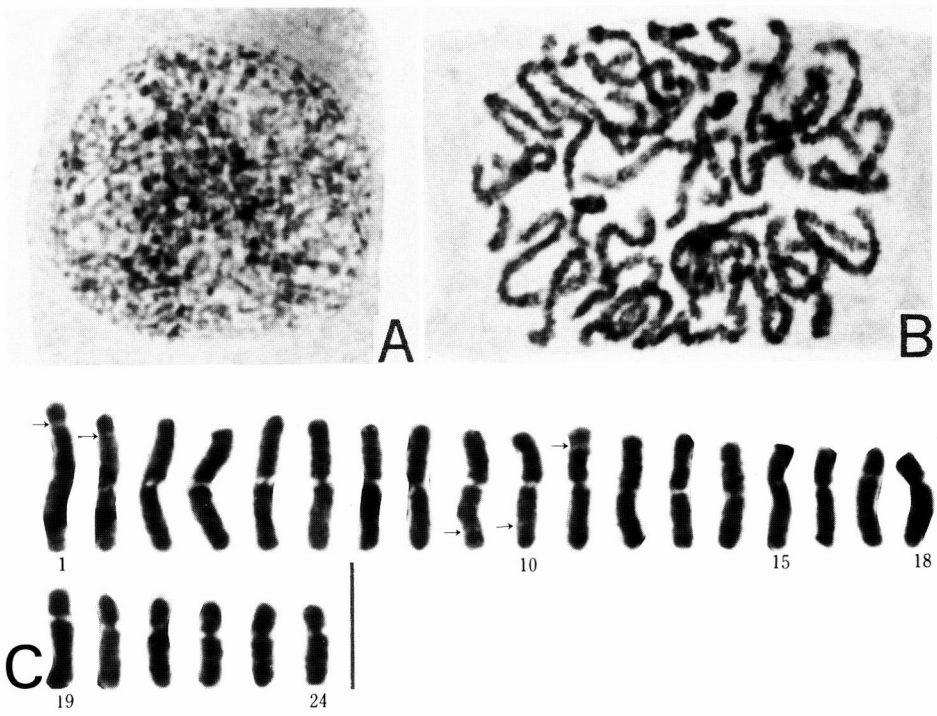

Fig. 6. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Abies sachalinensis* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 6A) and at mitotic prophase (Fig. 6B) were observed similar in karyomorphology to those observed in *A. concolor* and thus were categorized to be the complex chromocenter type and the continuous type, respectively. Two to six nucleoli were observed in each nucleus.

The chromosomes in each set at mitotic metaphase varied in length from 11.4–6.6 μm. Seven pairs of chromosomes were large-sized and the other five pairs were medium-sized. The chromosome complement showed bimodal variation in length. Seven pairs of large chromosomes had the centromeres at their median regions. One pair of medium-sized chromosomes (the 8th pair) possessed the centromere at median-submedian region and the others at their submedian region (Fig. 6C). Secondary constrictions appeared at interstitial regions of their single arms of three pairs of large metacentric chromosomes (the 1st, 5th, 6th pairs). Number of secondary constrictions is identical to the number observed in pollen mitosis by Mergen & Lester (1961).

7. *Abies firma* Sieb. & Zucc., 2n=24, Fig. 7 (Japanese name : Momi)

Eleven young trees collected from three localities (Table 1) were used for karyomorphological observation. The chromosome number was counted to be 2n=24 in all plants, which confirmed the previous documents (Kanezawa 1949, Mergen & Burley 1964, Toyama & Kuroki 1967) excepting for a tetraploid count by Kanezawa (1949).

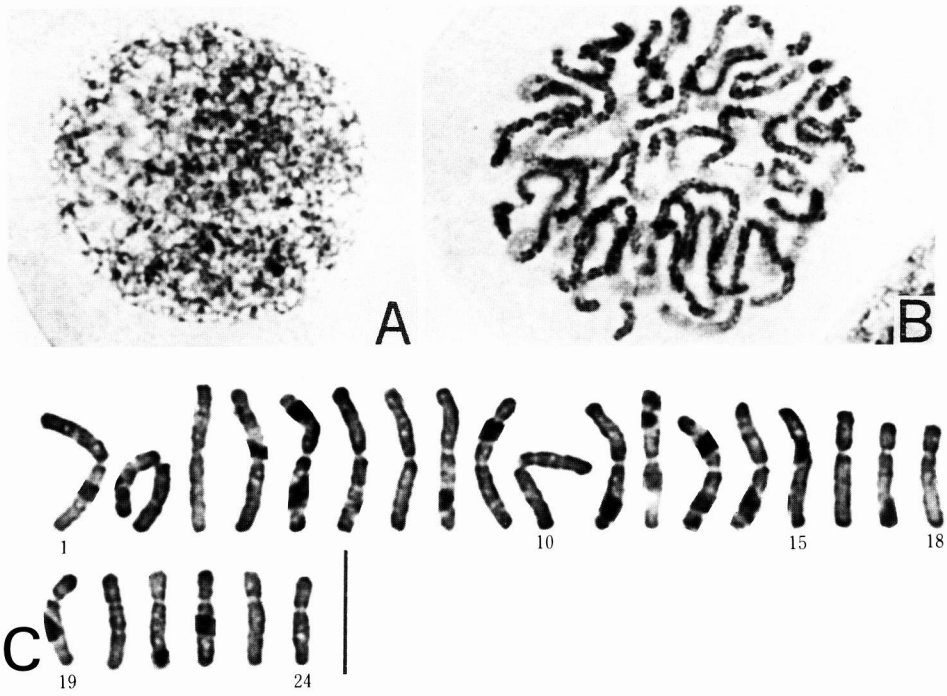

Fig. 7. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Abies firma* (2n=24). Bar indicates 10 μm.

The chromosomes at interphase (Fig. 7A) and mitotic prophase (Fig. 7B) were observed to be similar to those in *A. concolor* and were categorized to be the complex chromocenter type and the continuous type. Two to ten nucleoli were observed in each nucleus. The chromosomes in each set at mitotic metaphase varied in length from 11.9–7.0 μm. Seven pairs of chromosomes were clearly larger than the other five pairs and thus, the chromosome complement showed bimodality. The centromeres of the large chromosomes were located at median regions and those of medium-sized chromosomes were located at submedian regions (Fig. 7C). Thus, karyomorphological features are similar to those reported by Mergen & Burley (1964). Secondary constrictions were frequently observed at interstitial regions of several chromosomes but their locations were not determined in this observation.

8. *Abies homolepis* Sieb. & Zucc., 2n=24, Fig. 8 (Japanese name : Urajiro-momi)

Among the seeds collected at a locality and juvenile trees of a few years old collected at two localities (Table 1), 15 seedlings and 8 plants growing in pots were used for cytological investigation. The chromosome numbers counted were all 2n=24 which confirmed the previous document by Price *et al.* (1973).

Morphology of chromosomes at interphase (Fig. 8A) and at mitotic prophase (Fig. 8B) of this species was observed to be similar to that in *A. concolor* and was categorized to be the complex chromocenter type and the continuous type, respectively. The chromosomes

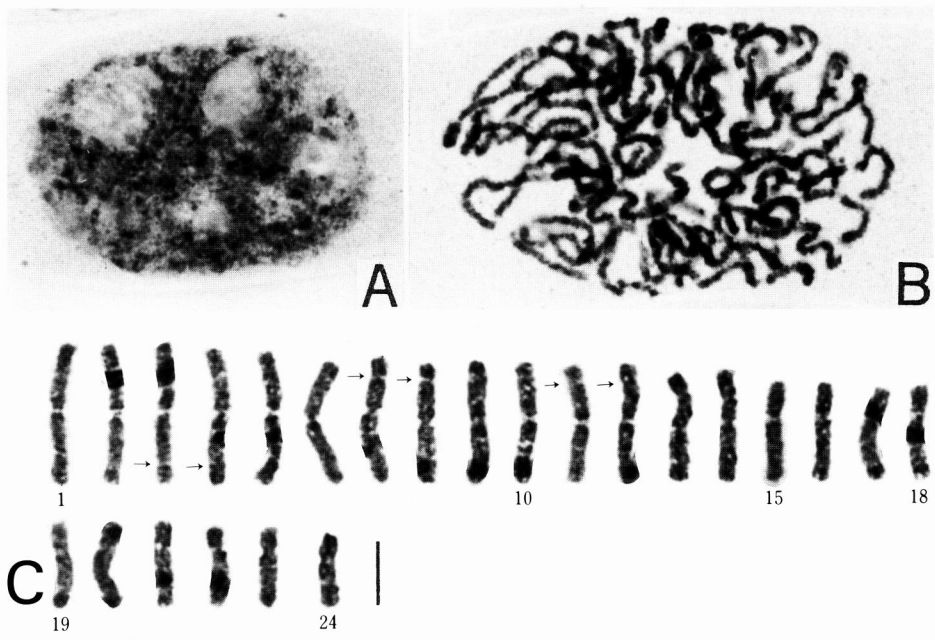

Fig. 8. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Abies homolepis* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

in each set at mitotic metaphase varied in length from 11.5–5.9 μm. Seven pairs of chromosomes were larger than the other pairs and the chromosome complement showed bimodal variation in length. All pairs of the large-sized chromosomes possessed the centromeres at their median positions and five pairs of medium-sized chromosomes possessed the centromeres at their submedian positions (Fig. 8C). Secondary constrictions appeared at interstitial regions of one arm in three pairs of large metacentric chromosomes (the 2nd, 4th, 6th pairs).

9. *Abies mariesii* Mast., 2n=24, Fig. 9 (Japanese name : Aomori-todo-matsu)

The seeds collected at Hatimantai, Iwate Pref., Japan, germinated, and their root tips were harvested from 40 seedlings for cytological observation. The chromosome count of 2n=24 in all metaphase plates of all plants studied is here recorded for the first time.

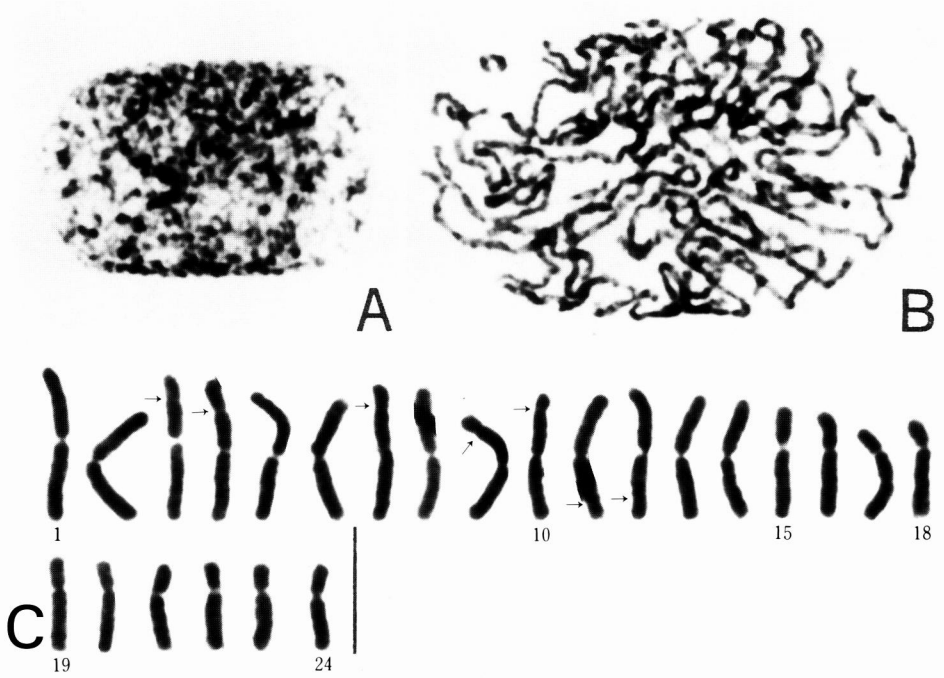

Fig. 9. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Abies mariesii* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 9A) and mitotic prophase (Fig. 9B) showed similar morphological characters to those of *A. concolor* and were considered to be the complex chromocenter type and the continuous type. The chromosomes of each set at mitotic metaphase varied bimodally in length from 12.7–6.9 μm. Seven pairs of large chromosomes were metacentric and the other five pairs of medium-sized chromosomes were submetacentric (Fig. 9C). Secondary constrictions appeared at interstitial regions of one arm of four pairs of large metacentric chromosomes (the 2nd, 4th, 5th, 6th pairs).

10. *Abies balsamea* (L.) Mill., 2n=24, Fig. 10

The seeds used were collected from Canada (Table 1) and were germinated. Root tips of 20 seedlings were examined cytologically and their chromosome number was determined to be 2n=24. This chromosome number confirms the previous reports by Miyake (1903a) and Price *et al.* (1973).

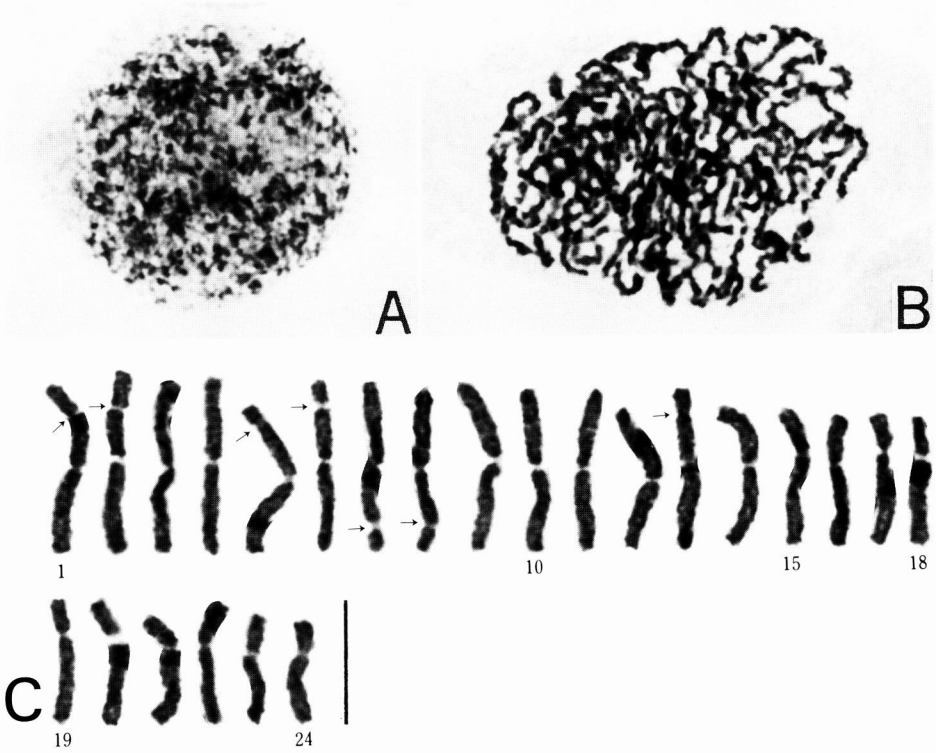

Fig. 10. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Abies balsamea* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

Morphology of chromosomes at interphase (Fig. 10A) and at mitotic prophase (Fig. 10B) was observed to be very similar to that in *A. concolor* and was categorized the complex chromocenter type and the continuous type, respectively. The chromosome complement at mitotic metaphase showed bimodal length variation. Seven pairs of large chromosomes varied gradually in length from 14.4–12.7 μm while five pairs of medium-sized chromosomes also did from 11.4–9.1 μm. All large chromosomes were metacentric and all medium-sized chromosomes were submetacentric (Fig. 10C). Secondary constrictions appeared at interstitial regions of their single arms on four pairs of large metacentric chromosomes (the 1st, 3rd, 4th, 7th pairs).

11. *Keteleeria davidiana* (Bertr.) Beissn., 2n=24, Table 3 and Fig. 11

For chromosomal investigation the seeds and two cuttings (Table 1) were used. The

chromosome number in all plants of this species was 2n=24, which was identical to the number reported in *K. davidiana* var. *formosana* by Sugihara (1942, 1943) and Kuo *et al.* (1972).

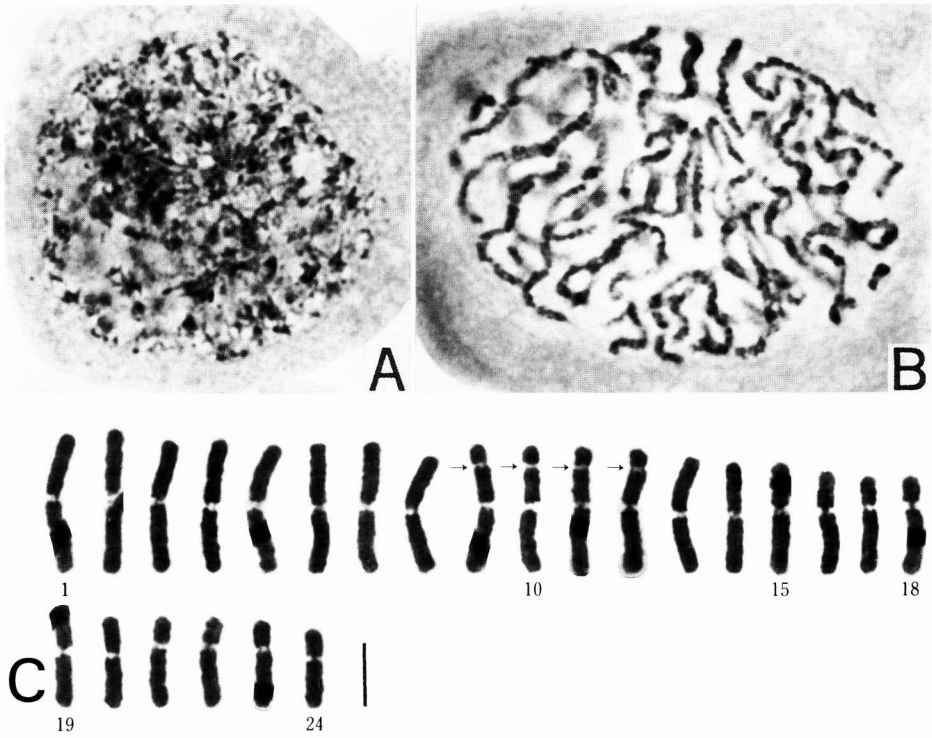

Fig. 11. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Keteleeria davidiana* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

The chromosomes at interphase formed several darkly stained chromatin blocks. The blocks appeared to be spherical shape and 1.3–1.5 μm diameter. Some of the chromatins formed many chromomeric granules and fibrous threads which homogeneously dispersed over nucleus (Fig. 11A). Morphology of chromosomes at interphase is categorized to be the complex chromocenter type. One to four nucleoli were observed in every nucleus.

The chromosomes at mitotic prophase homogeneously condensed at any time with similar width among the parts (Fig. 11B). The condensation pattern of prophase chromosomes is considered to be the continuous type.

The chromosomes of the complement at mitotic metaphase varied in length from 11.3–6.4 μm. Seven pairs of chromosomes were larger than the other five pairs. In each of these chromosomes group with respect to the chromosome length the chromosomes gradually varied in length. The chromosome complement showed bimodal variation in length. All of the large chromosomes were metacentric, three pairs of medium-sized chromosomes (the 9th, 11th, 12th pairs) were submetacentric and the other medium-sized chromosomes were

meta-submetacentric (Table 3, Fig. 11C). Two pairs of large metacentric chromosomes (the 5th and 6th pairs) possessed secondary constrictions at interstitial regions of their short arms. The karyotype at metaphase considerably differs from that reported in a variety of the species by Kuo *et al.* (1972).

12. *Pseudotsuga menziesii* (Mirb.) Franco, 2n=26, Table 4 and Fig. 12

The seeds collected from four localities and seven juvenile trees (Table 1) were used for chromosomal observation. Fourty-four plants of this species showed the chromosome number of 2n=26 which was same as that reported by many authors (*e.g.*, Sax & Sax 1933, Zenke 1953, Durrieu-Vabre 1958, 1971, Barner & Christiansen 1962, Christiansen 1963, Owens 1967, Thomas & Ching 1968, Livingston 1971, Doerksen & Ching 1972, Price *et al.* 1973, De-Vescovi & Sziklai 1975, Muraya *et al.* 1976, Sasaki 1976, Wochok *et al.* 1980, El-Kassaby *et al.* 1983). However, the chromosome numbers of 2n=24 and 25 reported for this species by Durrieu-Vabre (1958, 1971) were not observed in the present observation.

The chromosomes at interphase formed many chromomeric granules and fibrous chromatin that dispersed homogeneously over nucleus and formed several spherical heteropycnotic bodies (Fig. 12A). Morphology of chromosomes at interphase is considered to be the complex chromocenter type. The chromosomes at mitotic prophase condensed homogeneously at any time and any position (Fig. 12B) and, therefore, were categorized to

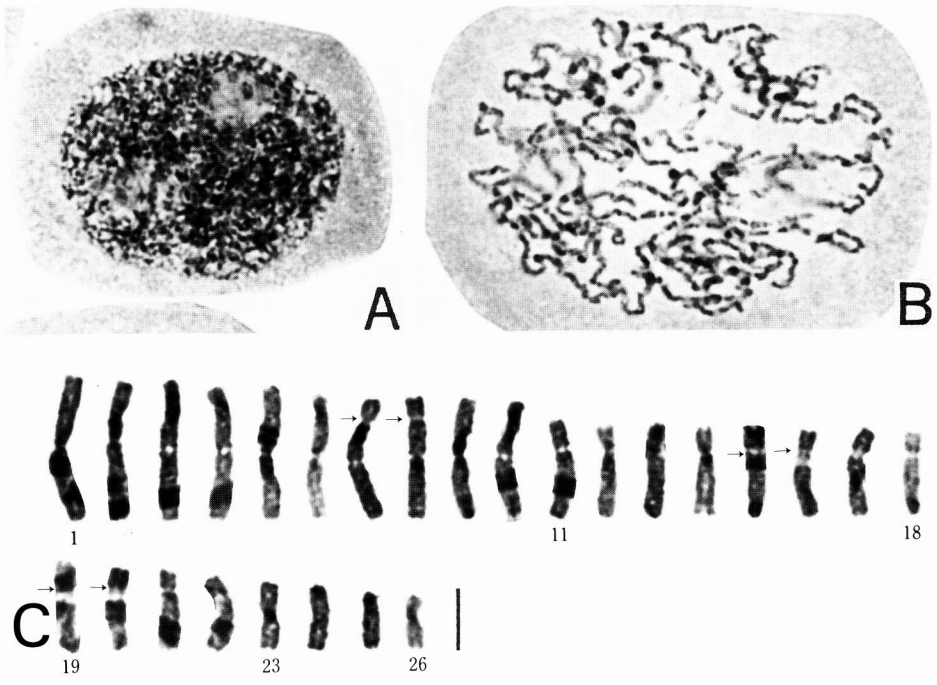

Fig. 12. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pseudotsuga menziesii* (2n=26). Bar indicates 5 μm and arrows indicate secondary constrictions.

be the continuous type. Among twenty-six metaphase chromosomes of the complement varied in length from 11.5-4.2 μm, five pairs were large-sized, six pairs were medium-sized and the other two pairs were small-sized. The chromosome complement at metaphase varied trimodally in length. In each chromosome size group of trimodality, the chromosome length varied gradually. Ten large-sized chromosomes showed the centromeres at median positions, 12 medium-sized chromosomes showed the centromeres at submedian positions, and four small-sized chromosomes showed the centromeres at terminal positions (Table 4, Fig. 12C). A pair of large metacentric chromosomes (the 4th pair) and two pairs of medium-sized submetacentric chromosomes (the 8th and 10th pairs) possessed secondary constrictions on their one arms; interstitial regions of the large-sized chromosomes and proximally interstitial regions of the medium-sized chromosomes had secondary constrictions. The large metacentric chromosomes with secondary constriction on one arms also possessed the small constriction at distally interstitial region on the other arms. The karyotype at metaphase is essentially similar to that reported by Christiansen (1963), Owens (1967), Durrieu-Vabre (1971), Doerksen & Ching 1972, De Vescovi & Sziklai (1975), Muraya *et al.* (1976), Thomas & Ching (1968), Wochok *et al.* (1980) and El-Kassaby *et al.* (1983) with exception of number and location of secondary constrictions.

13. *Pseudotsuga japonica* (Shiras.) Beissn., 2n=24, Table 5 and Fig. 13 (Japanese name : Toga-sawara)

Three juvenile trees were collected from two localities (Table 1) and seeds were collected from Mt. Yasudagawa, Kouchi Pref., Japan. Root tips of 20 seedlings and three juvenile plants were used for cytological observation. The chromosome number of this species was 2n=24, and different from that of *P. menziesii*. This chromosome count confirms the previous reports by Doerksen & Ching (1972) and El-Kassaby *et al.* (1983).

Morphology of the chromosomes at interphase (Fig. 13A) and at mitotic prophase (Fig. 13B) was observed to be similar to that observed in *P. menziesii*, and was categorized the complex chromocenter type and the continuous type, respectively.

The chromosome complement at mitotic metaphase was composed of 12 large-sized chromosomes and 12 medium-sized chromosomes and thus, showed a bimodal karyotype. The large-sized chromosomes varied in length from 11.5-9.7 μm and the medium-sized chromosomes from 7.5-6.1 μm. The centromeres in the large-sized chromosomes were located at median regions while those in the medium-sized chromosomes were located at submedian regions (Table 5, Fig. 13C). Two pairs (the 3rd and 5th pairs) of chromosomes possessed secondary constrictions at interstitial regions of one-side arms. The karyotype at mitotic metaphase is mostly coincided with that reported by Doerksen & Ching (1972) and El-Kassaby *et al.* (1983) excepting for number and location of secondary constriction.

14. *Tsuga canadensis* (L.) Carr., 2n=24, Table 6 and Fig. 14

Seeds collected from two localities (Table 1) were germinated and root tips of 15 seed-

lings were used for cytological observation. The chromosome number was shown to be 2n=24 in all preparations, which confirmed the previous counts (Murrill 1900, Sax & Sax 1933, Santamour 1963, Fahmy 1966).

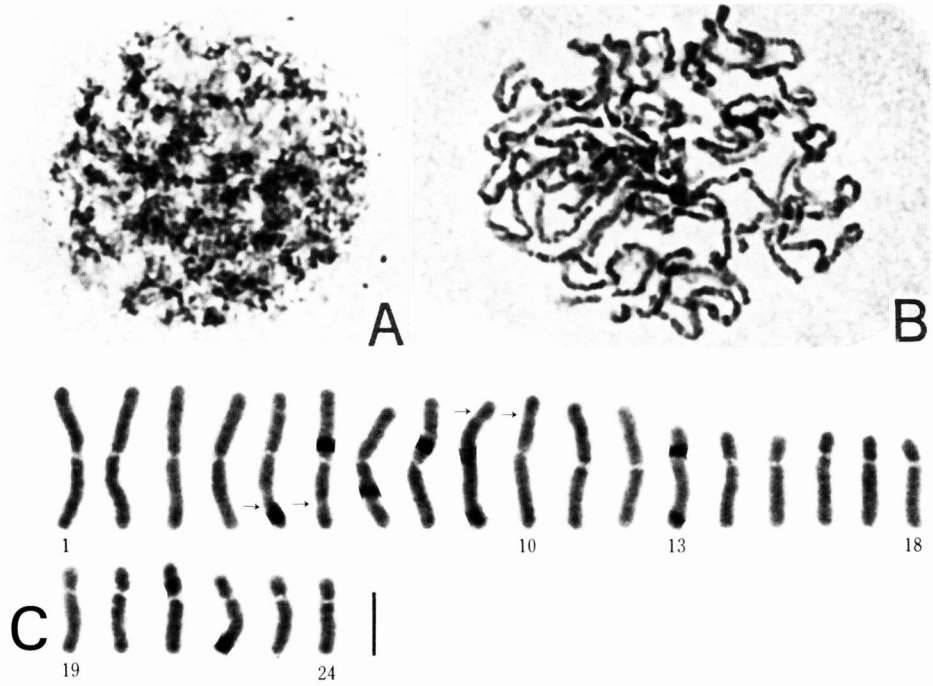

Fig. 13. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pseudotsuga japonica* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

The chromosomes at interphase were observed to be several spherical heteropycnotic bodies, many chromomeric granules and fibrous chromatin threads (Fig. 14A). The structures of chromatin scattered over the nucleus. Morphology of the chromosomes at interphase is categorized to be the complex chromocenter type. The chromosomes at mitotic prophase condensed homogeneously along the long axis (Fig. 14B) and were considered to be the continuous type.

At mitotic metaphase the chromosomes varied gradually in length from 10.8–6.2 μm. Eight pairs of chromosomes were larger than the other four pairs of chromosomes. Seven pairs of large-sized chromosomes and the 11th pair possessed their centromeres at median regions, the 8th pair possessed its centromere at median-submedian region and three pairs of medium-sized chromosomes (the 9th, 10th, 12th pairs) possessed their centromeres at submedian regions (Table 6, Fig. 14C). Three pairs of large metacentric chromosomes (the 3rd, 5th, 7th pairs) possessed secondary constrictions at interstitial regions of their one-side arms. The feature of metaphase chromosomes is generally similar to that of the previous report by Sax & Sax (1933) excepting for number and location of secondary constriction.

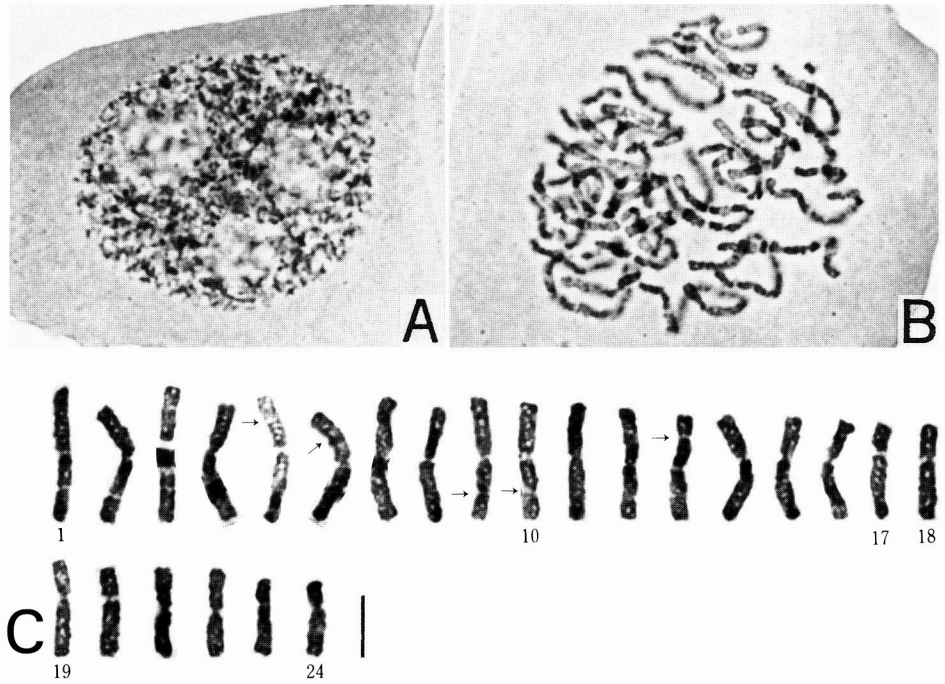

Fig. 14. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Tsuga canadensis* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

15. *Tsuga heterophylla* (Raf.) Sarg., 2n=24, Fig. 15

Seeds collected in two sources in North America (Table 1) were germinated and their root tips were used for cytological observations. The chromosome number was 2n=24 in all 17 specimens, which confirmed the previous count (Durrieu-Vabre 1954).

The chromosomes at interphase (Fig. 15A) and mitotic prophase (Fig. 15B) were similar to those observed in *T. canadensis*. Morphology of the chromosomes at interphase and prophase is categorized to be the complex chromocenter type and the continuous type, respectively. The chromosomes at mitotic metaphase varied gradually in length from 10.8–6.1 μm. Seven pairs of larger chromosomes possessed centromeres at median positions, the 8th and 11th pairs possessed centromeres at median-submedian positions and the other medium-sized chromosomes (the 9th, 10th, 12th pairs) possessed their centromeres at submedian positions (Fig. 15C). Secondary constrictions appeared at interstitial regions of one-side arms of the 1st and 3rd pairs of chromosomes.

16. *Tsuga caroliniana* Engelm., 2n=24, Fig. 16

Seeds obtained from U.S.A. were germinated and the root tips of 5 seedlings were examined cytologically. The chromosome number of 2n=24 was counted in all plants studied and confirmed the previous document (Sax & Sax 1933).

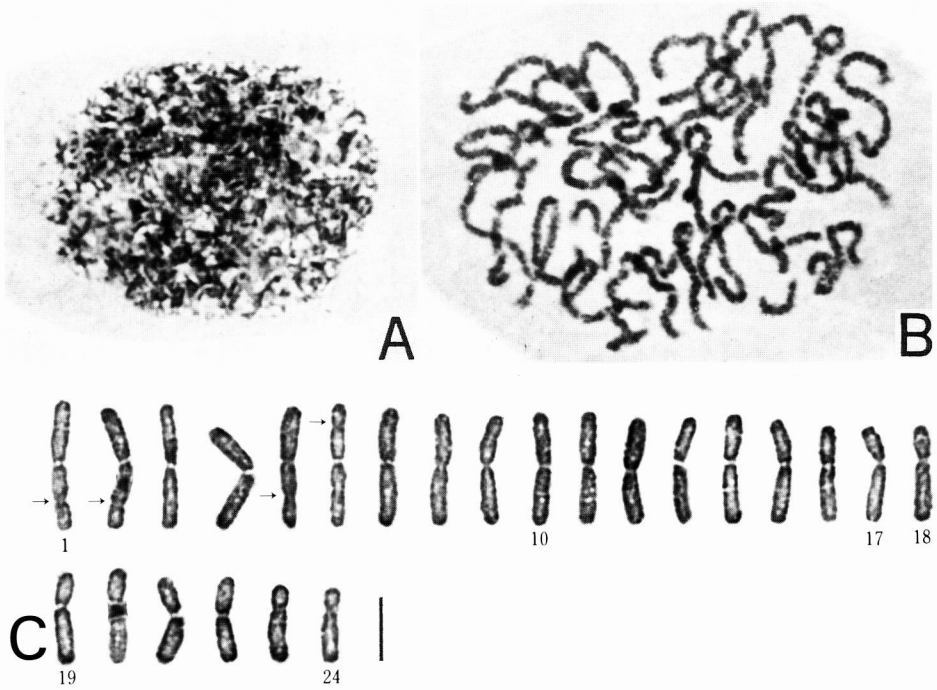

Fig. 15. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Tsuga heterophylla* (2n = 24). Bar indicates 5 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 16A) and at mitotic prophase (Fig. 16B) were similar to those in *T. canadensis*. Morphology of the chromosomes at interphase and prophase was categorized to be the complex chromocenter type and the continuous type, respectively. The mitotic chromosomes in each complement at metaphase varied gradually in length from 12.3–7.0 μm. Six larger pairs and the 8th pair of chromosomes had their centromeres at median regions, the 7th and 11th pairs had their centromeres at median–submedian regions and the other three medium-sized pairs (the 9th, 10th, 12th pairs) had their centromeres at submedian regions (Fig. 16C). Secondary constrictions were located at interstitial regions of the short arms of the 3rd and 4th pairs of chromosomes. The feature of metaphase chromosomes is generally similar to that previously reported by Sax & Sax (1933) except for number and location of secondary constriction.

17. *Tsuga sieboldii* Carr., 2n = 24, Fig. 17 (Japanese name : Tsuga)

Twenty young trees were collected at three localities in Japan (Table 1) and the young leaves of shoot apex were used for cytological observation. They showed the chromosome number of 2n = 24, confirming the previous count (Santamour 1963).

The chromosomes at interphase (Fig. 17A) and mitotic prophase (Fig. 17B) were similar to those observed in *T. canadensis* and were categorized to be the complex chromocenter type and the continuous type, respectively. As many as six nucleoli were

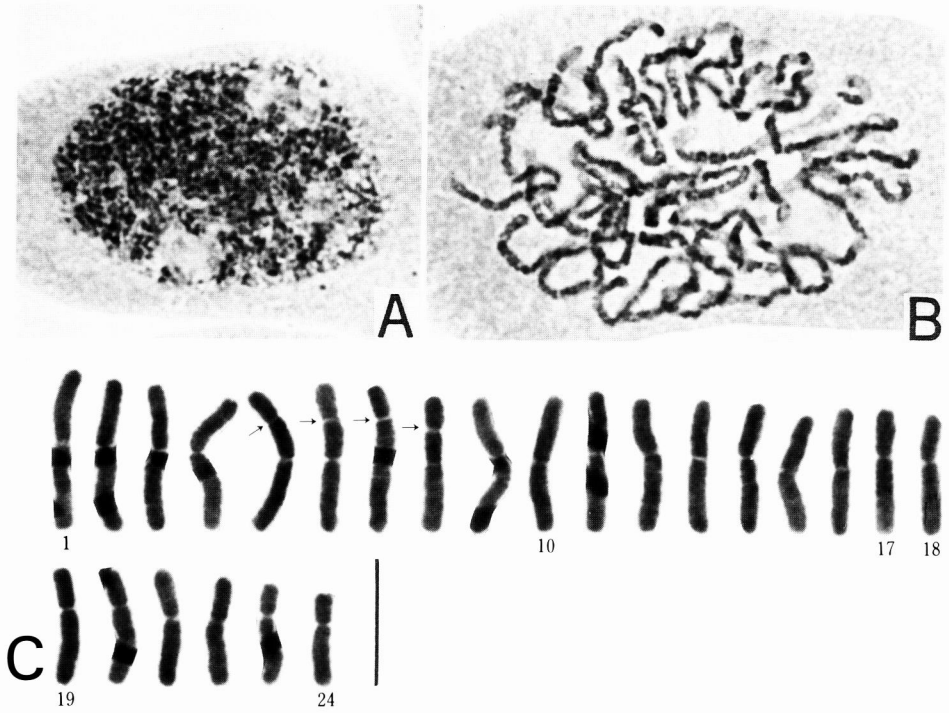

Fig. 16. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Tsuga caroliniana* (2n = 24). Bar indicates 10 μm and arrows indicate secondary constrictions.

observed in each nucleus. The chromosomes in each compliment at mitotic metaphase varied gradually in length from 10.7–6.1 μm. The centromeres of seven pairs of larger chromosomes were placed at median regions, those of the 8th and 11th pairs of chromosomes were placed at median–submedian regions, and those of three pairs (the 9th, 10th, 12th pairs) of smaller chromosomes were placed at submedian regions (Fig. 17C). Secondary constrictions appeared at interstitial regions of several chromosomes, but their precise locations were not determined in this study.

18. *Tsuga diversifolia* (Maxim.) Mast., 2n = 24, Fig. 18 (Japanese name : Kome-tsuga)

Nine trees were collected from Mt. Higashiakaishi, Ehime Pref., Japan and their young leaves of shoot apex were used for chromosome study. The chromosome number of 2n = 24 was counted and confirmed the previous report (Santamour 1963).

The chromosomes at interphase (Fig. 18A) and mitotic prophase (Fig. 18B) were similar in karyomorphology to those in *T. canadensis* and were categorized to be the complex chromocenter type and the continuous type, respectively. The chromosomes in each mitotic metaphase cell varied gradually in length from 11.6–6.7 μm. Five pairs of the larger chromosomes and the 7th pair of chromosomes were metacentric, the 6th, 8th and 11th pairs of chromosomes were meta–submetacentric and three pairs of the smaller

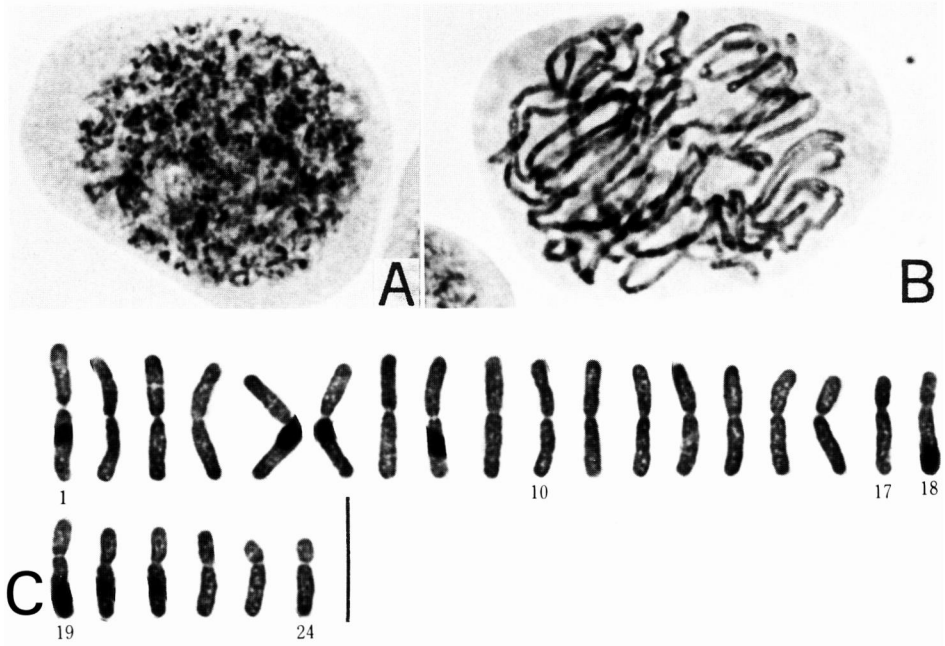

Fig. 17. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in young leaves cells of *Tsuga sieboldii* (2n = 24). Bar indicates 10 μm.

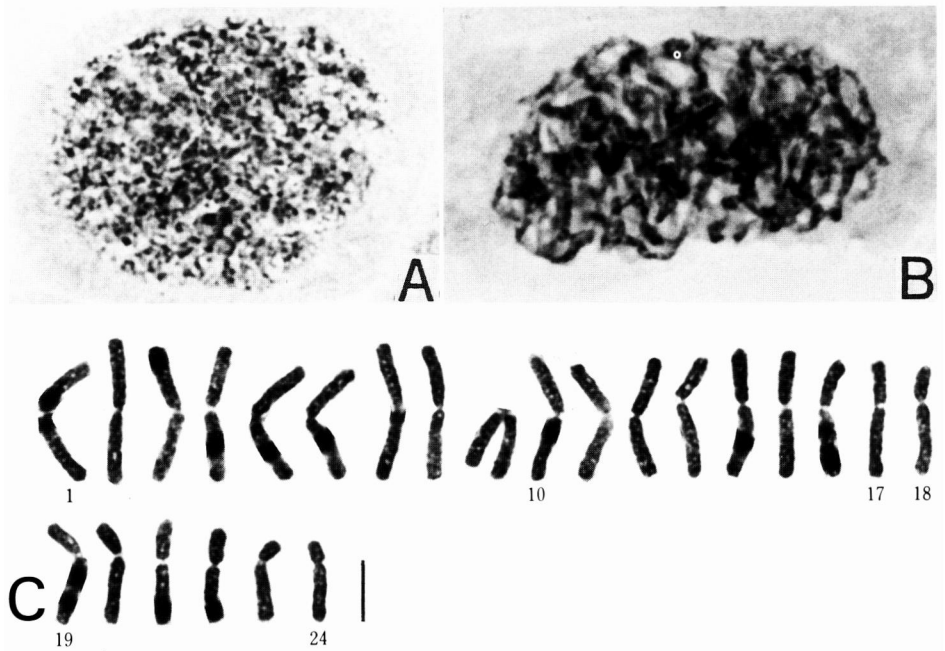

Fig. 18. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in young leaves cells of *Tsuga diversifolia* (2n = 24). Bar indicates 5 μm.

chromosomes (the 9th, 10th, 12th pairs) were submetacentric (Fig. 18C). Several metacentric chromosomes showed secondary constrictions at interstitial regions of their single arms, but location of the secondary constrictions was not determined in this observation.

19. *Tsuga chinensis* (Franch.) Pritz, 2n=24, Fig. 19

Seeds collected and supplied from the People's Republic of China (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number were counted to be 2n=24 which confirmed the previous report (Santamour 1963).

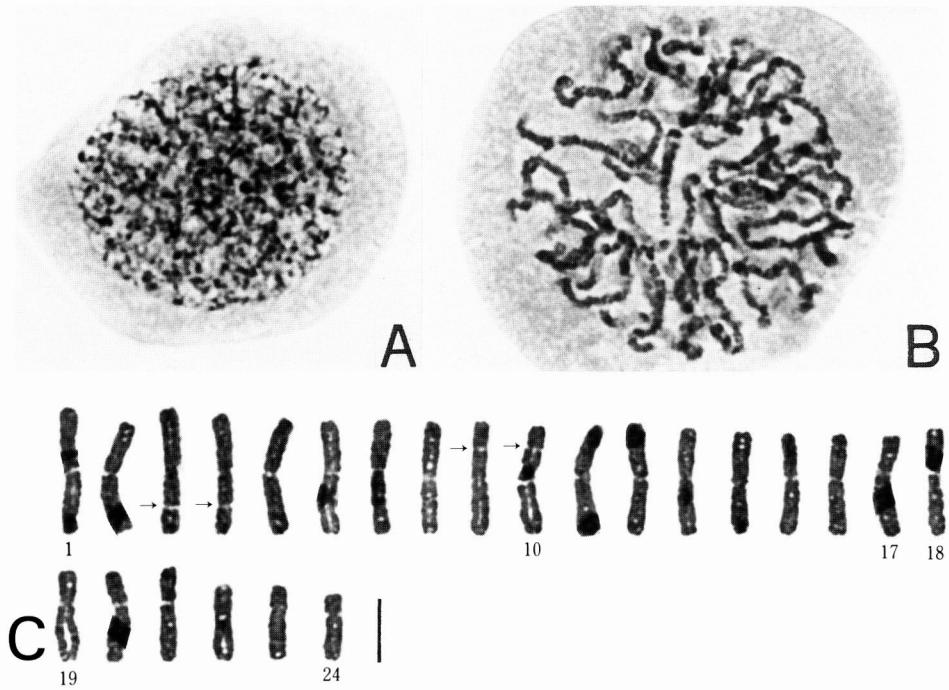

Fig. 19. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Tsuga chinensis* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 19A) and mitotic prophase (Fig. 19B) were similar in karyomorphology to those observed in *T. canadensis* and were categorized to be the complex chromocenter type and the continuous type, respectively. The chromosomes in each mitotic metaphase cell varied gradually in length from 10.5–5.6 μm. Eight pairs of the larger chromosomes had centromeres at median regions, the 11th pair of chromosomes had the centromere at median–submedian region, and three pairs of chromosomes (the 9th, 10th, 12th) had centromeres at submedian regions (Fig. 19C). Two pairs of metacentric chromosomes (the 2nd and 5th pairs) showed secondary constrictions at interstitial regions of their one–side arms.

20. *Picea abies* (L.) Karst., 2n=24, Table 7 and Fig. 20.

Seeds collected from two sources (Table 1) were germinated. Root tips of 35 seedlings and a juvenile plant were used for cytological observation. The chromosome number was counted to be 2n=24 which confirmed the previous reports (Miyake 1903b, Sax & Sax 1933, Andersson 1947, Santamour 1960, Simak & Happel 1966, Toyama & Kuroki 1967, Terasmaa 1971, 1972, 1975, Price *et al.* 1973, Sasaki 1976 and Karnosky & Setliff 1977).

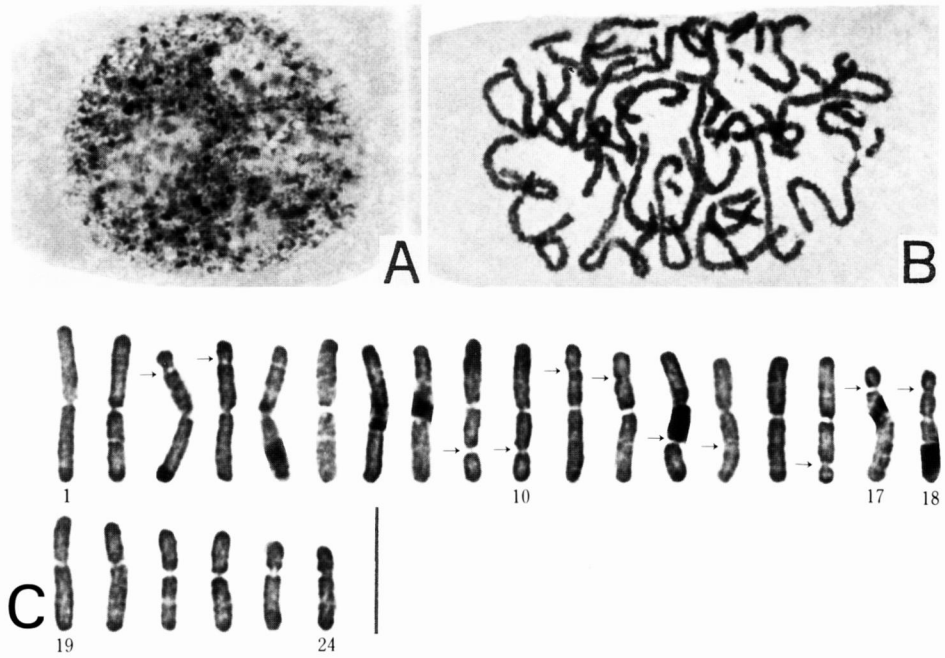

Fig. 20. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea abies* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase formed fibrous threads and many chromomeric granules were found scattered in nuclear space. Twenty to thirty heteropycnotic bodies were observed in each nucleus (Fig. 20A). The heteropycnotic bodies were densely aggregated in spherical shape. Morphology of chromosomes at interphase is categorized to be the complex chromocenter type. Two to 12 nucleoli were found in each nucleus. The chromosome at mitotic prophase were observed to be homogeneous threads with constant width (Fig. 20B). The width of chromosomes increased gradually from early prophase to metaphase. The pattern of condensation of chromosomes at prophase is categorized to be the continuous type.

The chromosomes at mitotic metaphase varied in length from 12.8–7.1 μm. The first pair of chromosomes was remarkably large and four pairs of chromosomes were distinctly smaller. A pair of small chromosomes (the 12th pair) possessed the centromere at submedian region, two pairs (the 7th and 10th) centromeres at median–submedian regions and the

other pairs of chromosomes centromeres at median regions (Table 7, Fig. 20C). Secondary constrictions were observed at interstitial regions of one-side arm of four pairs of chromosomes (the 2nd, 4th, 7th, 9th). The karyomorphological feature of mitotic metaphase is generally similar to that reported by Terasmaa (1971, 1972, 1975) with slight different in location of secondary constriction.

21. *Picea orientalis* (L.) Link., 2n=24, Fig. 21.

Seeds (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number of 2n=24 was counted in all preparations. The chromosome count verified the previous count reported by Santamour (1960).

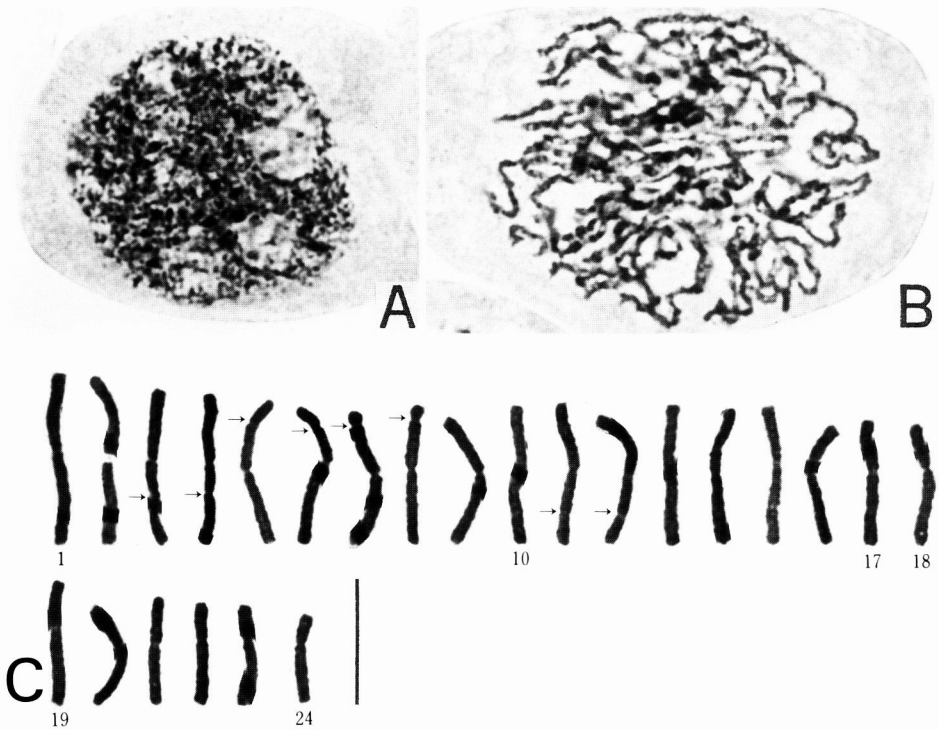

Fig. 21. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea orientalis* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 21A) and mitotic prophase (Fig. 21B) were similar in karyomorphology to those of *P. abies* and were categorized to be the complex chromocenter type and the continuous type, respectively. The chromosomes of each complement at metaphase varied gradually in length from 13.8–7.4 μm. The longest pair and four short pairs of chromosomes were easily distinguished. Most of the chromosomes showed their centromeres at median regions, two pairs (the 8th and 11th) their centromeres at median-submedian regions and three pairs of the smaller chromosomes (the 9th, 10th, 12th

pairs) their centromeres at submedian regions (Fig. 21C). Secondary constrictions were observed at interstitial region of one-side arm in each of four pairs of large metacentric chromosomes (the 2nd, 4th, 5th, 7th pairs). Small constrictions appeared sometimes at interstitial regions of some chromosomes.

22. *Picea glauca* (Moench) Voss, 2n=24, Fig. 22

Seeds obtained from Canada (Table 1) were germinated and 20 root tips were used for cytological observation. The chromosome number was 2n=24 in all preparations. Thus, this chromosome count verified the previous documents reported by Sax & Sax (1933), Santamour (1960), Risser (1964), Sasaki (1976) and Teoh & Rees (1976, 1977).

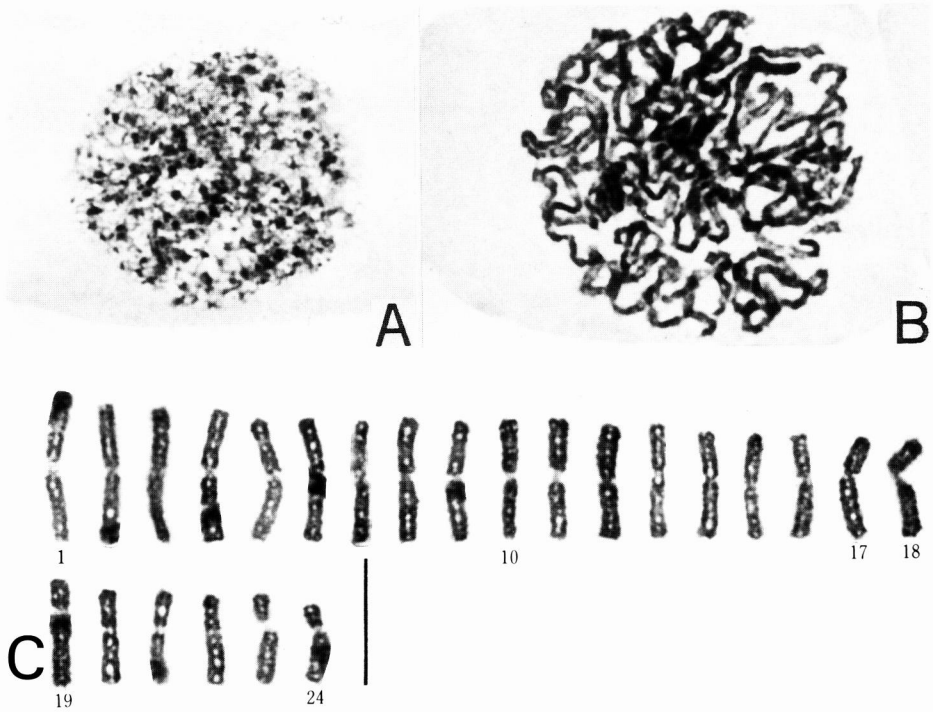

Fig. 22. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea glauca* (2n=24). Bar indicates 10 μm.

The chromosomes at interphase (Fig. 22A) and mitotic prophase (Fig. 22B) were similar in karyomorphology to those in *P. abies* and were categorized to be the complex chromocenter type and the continuous type, respectively. The chromosomes of each complement at metaphase varied in length gradually from 12.2-6.4 μm. The pair of the longest chromosomes and four pairs of the shorter chromosomes were easily distinguished. Most of the chromosomes had their centromeres at median regions, two pairs (the 10th and 11th) their centromeres at median-submedian regions and two pairs of shorter chromosomes (the 9th, 12th) their centromeres at submedium regions (Fig. 22C). Second-

ary constrictions were observed at interstitial regions of several large metacentric chromosomes but their locations were not determined. Karyomorphological feature of metaphase chromosomes is essentially similar to that reported by Sasaki (1976).

23. *Picea mariana* (Mill.) B.S.P., 2n=24, Fig. 23

Seeds collected from two localities in Canada (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number of 2n=24 was counted in all preparations. This chromosome count confirms the previous count reported by Sax & Sax (1933) and Morgenstern (1962).

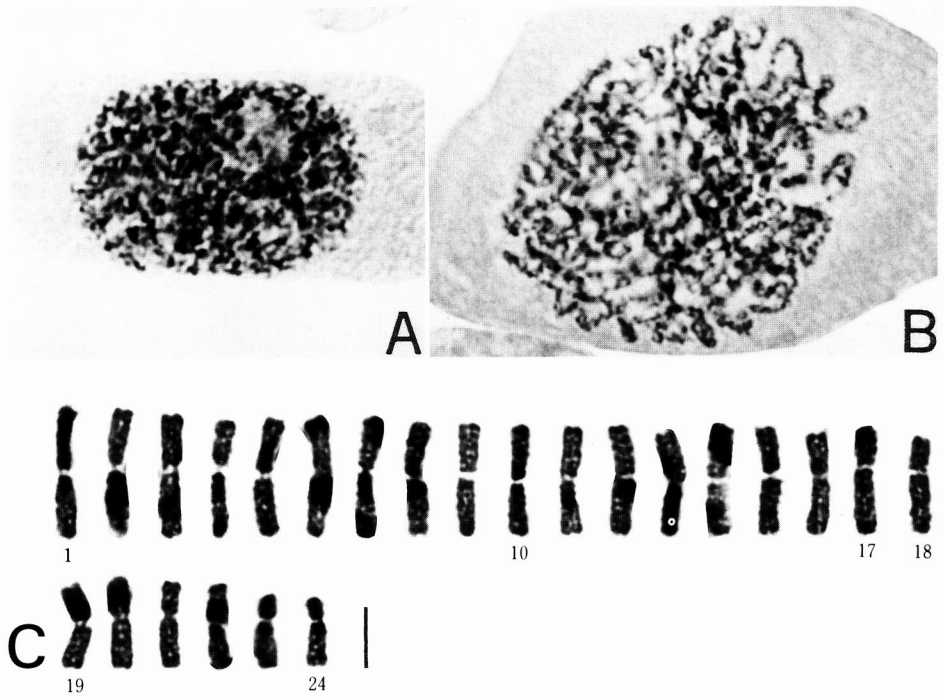

Fig. 23. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea mariana* (2n=24). Bar indicates 5 μm.

The chromosomes at interphase (Fig. 23A) and mitotic prophase (Fig. 23B) were similar in karyomorphology to those in *P. abies* and were categorized to be the complex chromocenter type and the continuous type, respectively. A gradual decrease in chromosome size was observed in the metaphase karyotype from the longest chromosomes of 10.5 μm to the shortest chromosome of 5.7 μm. The longest chromosomes and three pairs of short chromosomes were easily distinguished. Most of the chromosomes contained their centromeres at median regions, while the 11th pair of chromosomes contained at median–submedian region, and two pairs of shorter chromosomes (the 9th and 12th pairs) their centromeres at submedium regions (Fig. 23C). Secondary constrictions were observed at interstitial region of one of the arms in several large metacentric chromosomes but their

locations were not determined. The morphological feature of chromosomes at metaphase is generally similar to that reported by Morgenstern (1962).

24. *Picea rubens* Sarg., 2n=24, Fig. 24.

Seeds collected from two localities in Canada (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number counted was 2n=24, which verified the previous count reported by Santamour (1960) and Morgenstern (1962).

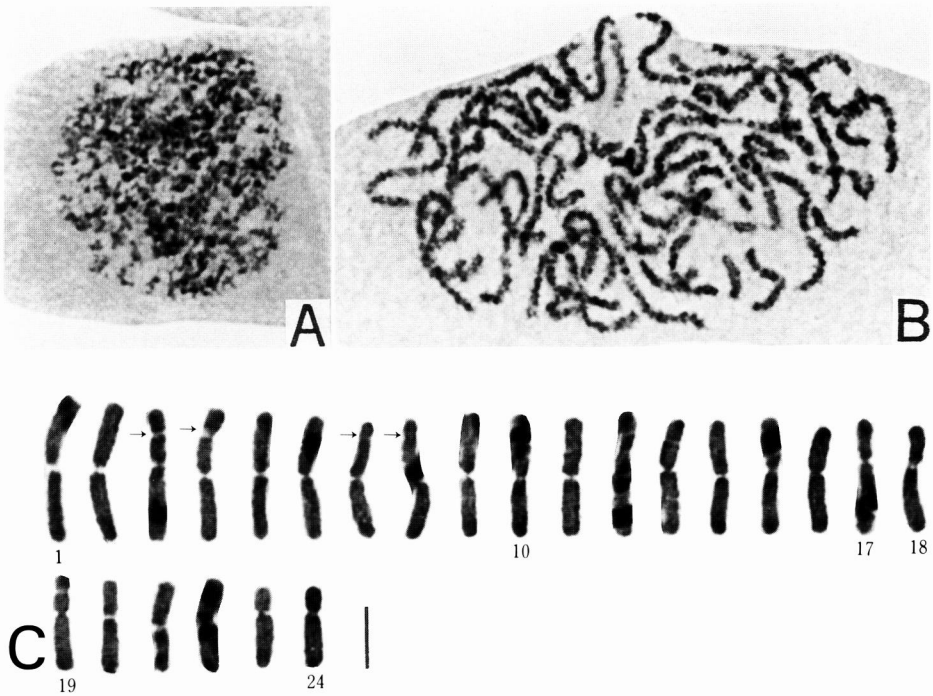

Fig. 24. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea rubens* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 24A) and mitotic prophase (Fig. 24B) were similar in karyomorphology to those in *P. abies* and were categorized to be the complex chromocenter type and the continuous type, respectively. The lengths of the chromosomes in each metaphase complement varied gradually from 11.4–6.3 μm. The longest chromosomes and four pairs of short chromosomes were easily distinguished. The majority of the metaphase chromosomes possessed a centromere at median region, while three pairs of shorter chromosomes (the 9th, 10th, 12th) had their centromeres at median–submedian or submedian regions (Fig. 24C). The morphological feature of chromosomes at metaphase is essentially similar to that reported by Morgenstern (1962). Secondary constrictions were observed at interstitial region of one of the arms of two pairs of chromosomes (the 2nd and 4th).

25. *Picea engelmannii* (Engelm.) Engelm., 2n=24, Fig. 25

Seeds collected from two localities in Canada (Table 1) were germinated and their root tips were used for cytological observation. These materials showed the chromosome number of 2n=24. This chromosome count verifies the previous count reported by Santamour (1960) and Teoh & Rees (1977).

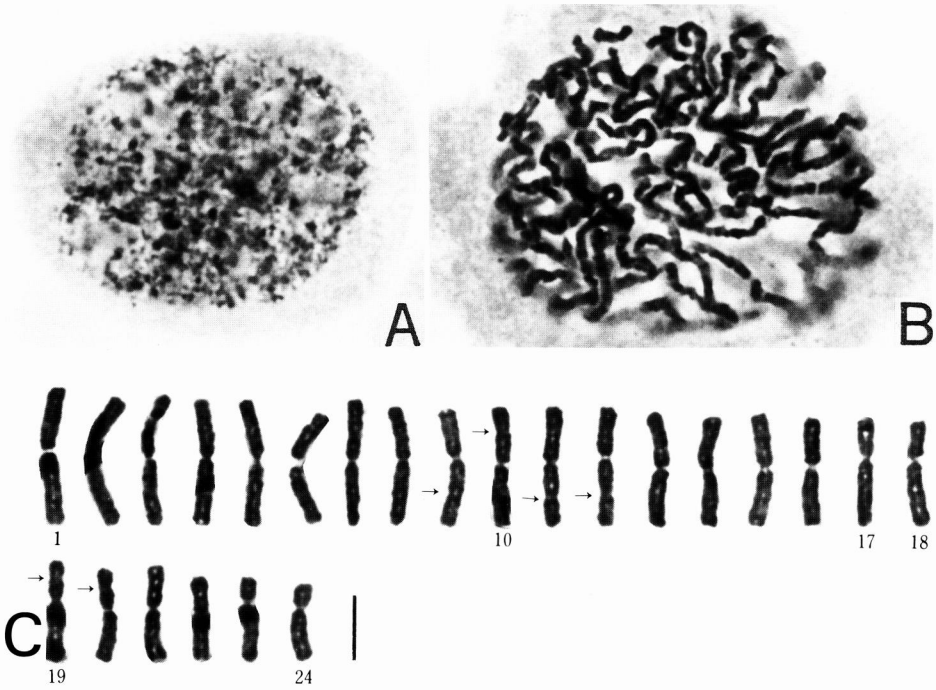

Fig. 25. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea engelmannii* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 25A) and mitotic prophase (Fig. 25B) were similar in karyomorphology to those in *P. abies* and were categorized to be the complex chromocenter type and the continuous type, respectively. The lengths of the chromosomes in each metaphase complement varied gradually from 11.2–6.4 μm. A pair of the longest chromosomes and four pairs of short chromosomes were distinct. Most of the metaphase chromosomes possessed their centromeres at median regions, while four pairs of shorter chromosomes (the 9th, 10th, 12th pairs) possessed their centromeres at median–submedian or submedian regions (Fig. 25C). Secondary constrictions were observed at interstitial regions of one of the arms on three pairs of chromosomes (the 5th, 6th, 10th pairs).

26. *Picea pungens* Engelm., 2n=24, Fig. 26

Seeds obtained from two sources (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number of 2n=24 was counted in all

preparations, and thus, verified the previous counts reported by Sax & Sax (1933) and Santamour (1960).

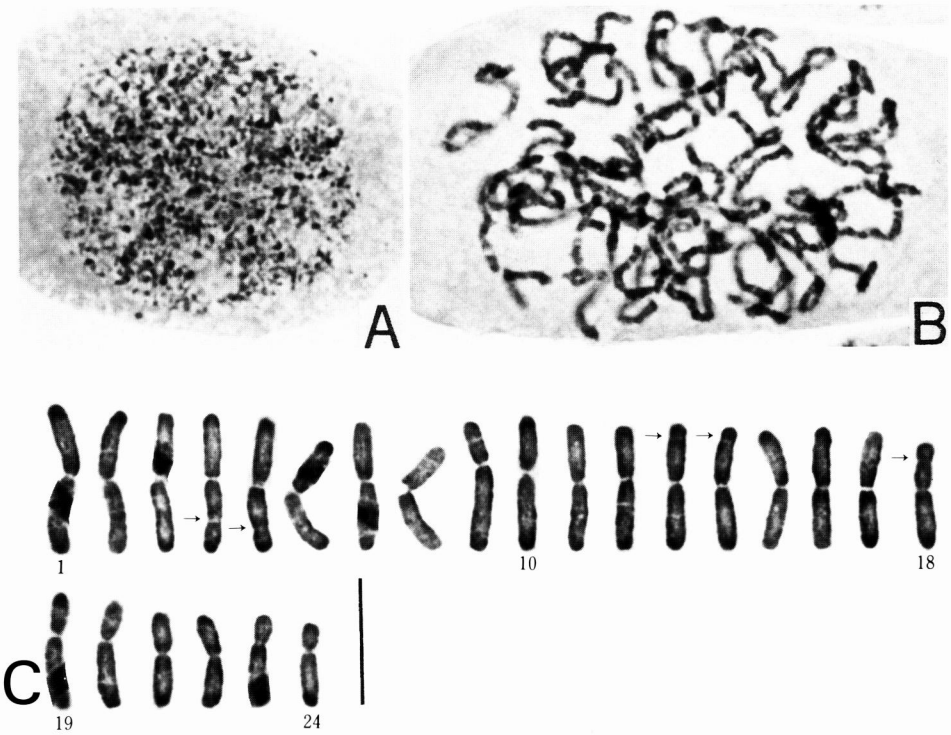

Fig. 26. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea pungens* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 26A) and mitotic prophase (Fig. 26B) were similar in karyomorphology to those in *P. abies* and were categorized to be the complex chromocenter type and the continuous type, respectively. The lengths of the chromosomes of the complement at metaphase varied gradually from 12.5–6.8 μm. A pair of the longest chromosomes and four pairs of small chromosomes were easily distinguished. Most of the chromosomes possessed their centromeres at median regions, while a pair of large chromosomes (the 5th pair) and two pairs of smaller chromosomes (the 10th, 12th pairs) possessed their centromeres at median–submedian or submedian regions (Fig. 26C). Secondary constrictions were frequently observed at interstitial regions of one or both arms on several pairs of metacentric chromosomes (the 2nd, 3rd, 7th, 9th).

27. *Picea bicolor* (Maxim.) Mayr, 2n=24, Fig. 27 (Japanese name : Ira-momi)

Seeds collected from two localities in Japan (Table 1) were germinated and their root tips were used for cytological observation. 2n=24 was counted for the chromosome number of this species. Thus, this chromosome count verifies the previous count reported by Santamour (1960).

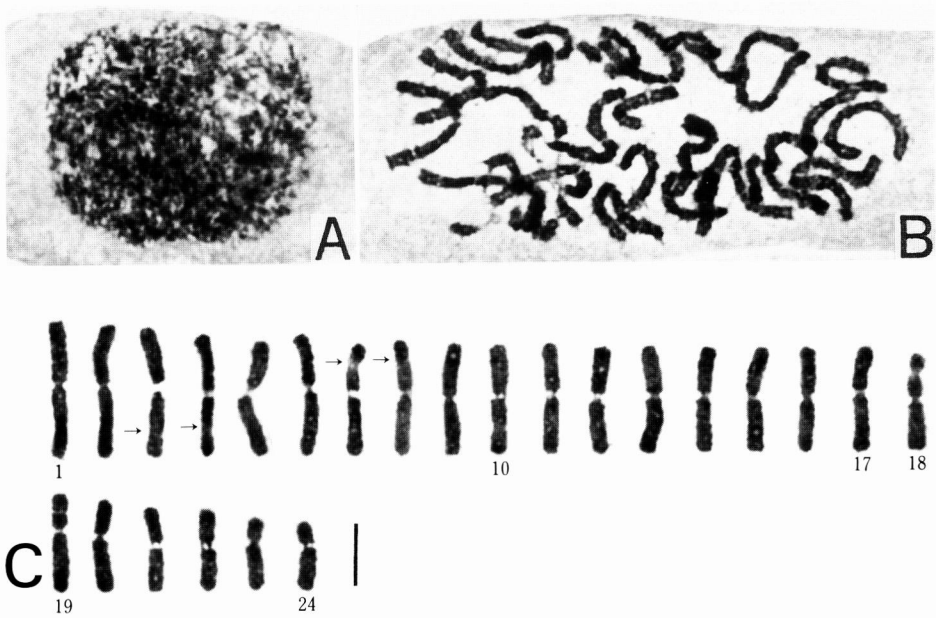

Fig. 27. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea bicolor* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 27A) and mitotic prophase (Fig. 27B) were similar in karyomorphology to those in *P. abies* and were categorized to be the complex chromocenter type and the continuous type, respectively. The lengths of the chromosomes in the metaphase complement varied gradually from 11.2–5.7 μm. A pair of the longest chromosomes and four pairs of short chromosomes were easily distinguished. Most of the chromosomes had their centromeres at median regions, while two pairs of shorter chromosomes (the 10th, 12th pairs) had their centromeres at submedium regions (Fig. 27C). Secondary constrictions were observed at interstitial regions of one of the arms on two pairs of metacentric chromosomes (the 2nd, 4th).

28. *Picea glehnii* (Fr. Schmidt) Mast., 2n=24, Fig. 28 (Japanese name : Aka-ezo-matsu)

Seeds collected from three localities in Hokkaido, Japan (Table 1) were germinated and their root tips were used for cytological observation. Most preparations showed the chromosome number of 2n=24. However, some preparations showed one or two B-chromosomes. Thus, this chromosome count verifies the previous count reported by Toyama & Kuroki (1967) and Sasaki (1976).

The chromosomes at interphase (Fig. 28A) and mitotic prophase (Fig. 28B) were similar in karyomorphology to those in *P. abies* and were categorized to be the complex chromocenter type and the continuous type, respectively. The lengths of the chromosomes in the complement at metaphase varied gradually from 12.7–6.7 μm. A pair of the longest chromosomes and four pairs of short chromosomes were easily distinguished. Most of the

chromosomes had their centromeres at median regions, while the 7th pair of chromosomes had the centromere at median-submedian region and two pairs of shorter chromosomes (the 10th, 12th pairs) their centromeres at submedian regions (Fig. 28C). Secondary constriction was constantly observed at interstitial region of the short arm of the 2nd pair of chromosomes. Several secondary constrictions were also observed occasionally on the other pairs of chromosomes but their locations were not determined. Karyomorphology of metaphase chromosomes is essentially similar to that reported by Sasaki (1976) with differences in number and location of secondary constriction.

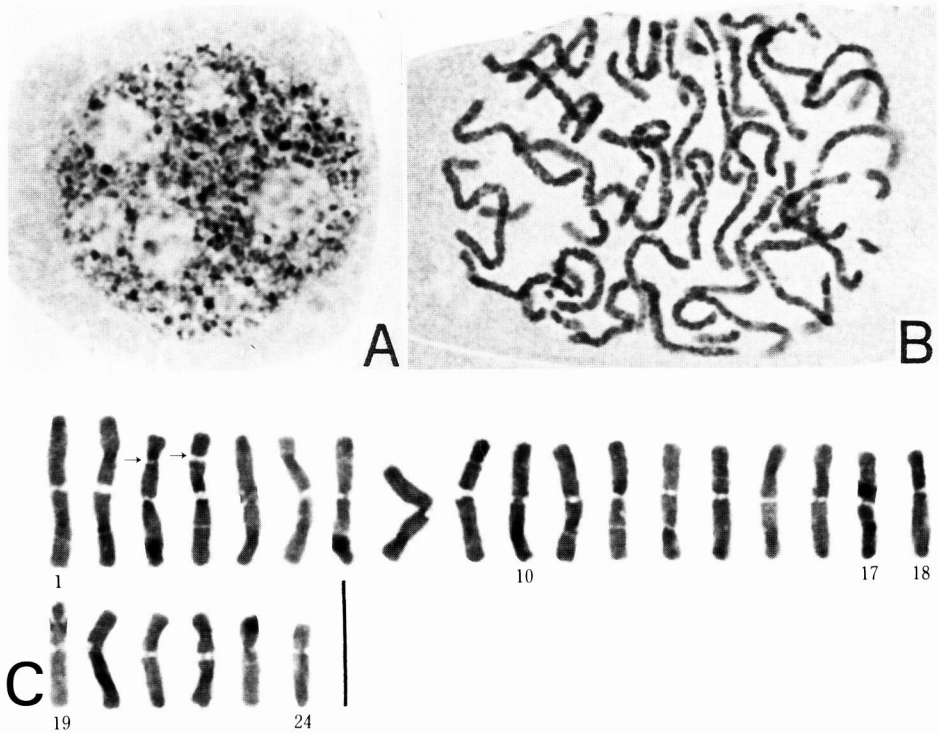

Fig. 28. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea glehnii* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

29. *Picea koyamae* Shiras., 2n=24, Fig. 29 (Japanese name : Yatsugatake-tō-hi)

Seeds collected from Suwa, Nagano Pref., Japan were germinated and their root tips were used for cytological observation. The chromosome number was counted to be 2n=24 in all preparations. Thus, the chromosome count verifies the previous count reported by Santamour (1960).

The chromosomes at interphase (Fig. 29A) and mitotic prophase (Fig. 29B) were similar in karyomorphology to those in *P. abies* and were categorized to be the complex chromocenter type and the continuous type, respectively. A gradual decrease in chromosome size from 10.5-5.4 μm was observed. A pair of the longest chromosomes and

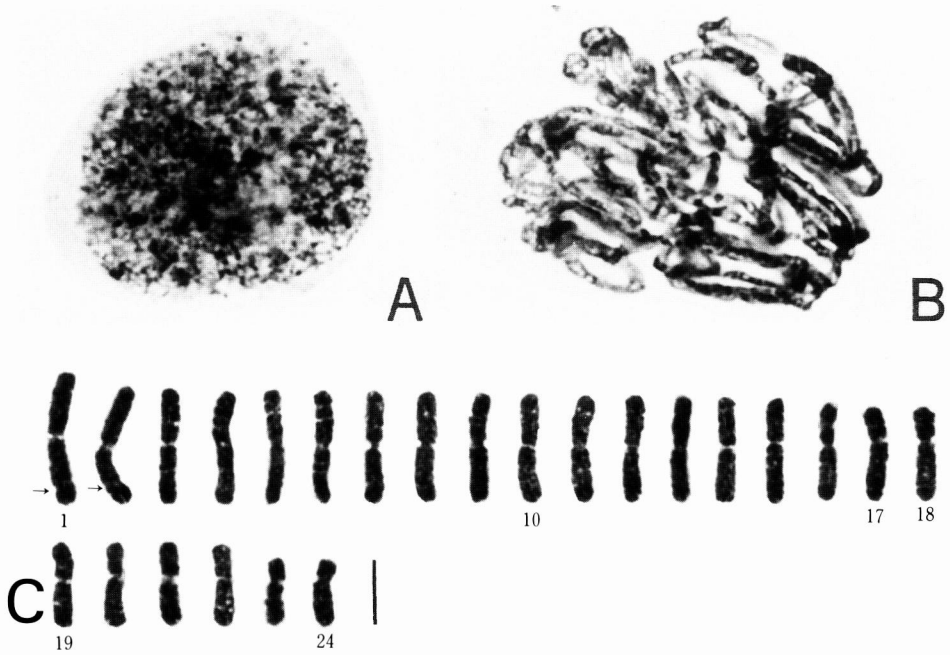

Fig. 29. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea koyamae* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

four pairs of short chromosomes were easily distinguished. The majority of the chromosomes showed a centromere at median region, while three pairs of smaller chromosomes (the 9th, 11th, 12th pairs) showed their centromeres at median–submedian or submedian regions (Fig. 29C). A pair of large chromosomes (the 8th pair) was faintly asymmetric. Secondary constriction was observed constantly at interstitial region of the 1st pair of metacentric chromosomes and other secondary constrictions were also often observed on several chromosomes.

30. *Picea polita* (Sieb. & Zucc.) Carr., 2n=24, Fig. 30 (Japanese name : Hari-momi)

Seeds and a cutting collected in Japan (Table 1) were used for cytological observation. The chromosomes number was counted to be 2n=24 in all mitotic metaphase plates.

The chromosomes at interphase (Fig. 30A) and mitotic prophase (Fig. 30B) were similar in karyomorphology to those in *P. abies* and were categorized to be the complex chromocenter type and the continuous type, respectively. The lengths of the chromosomes of the complement at metaphase showed a gradual decrease from 14.0–7.4 μm. A pair of the longest chromosomes and four pairs of short chromosomes were easily distinguished. Most of the chromosomes possessed their centromeres at median regions, while a pair of large chromosomes (the 8th pair) possessed the centromere at median–submedian region and three pairs of shorter chromosomes (the 9th, 10th, 12th pairs) their centromeres at submedian regions (Fig. 30C). Secondary constrictions frequently appeared at interstitial

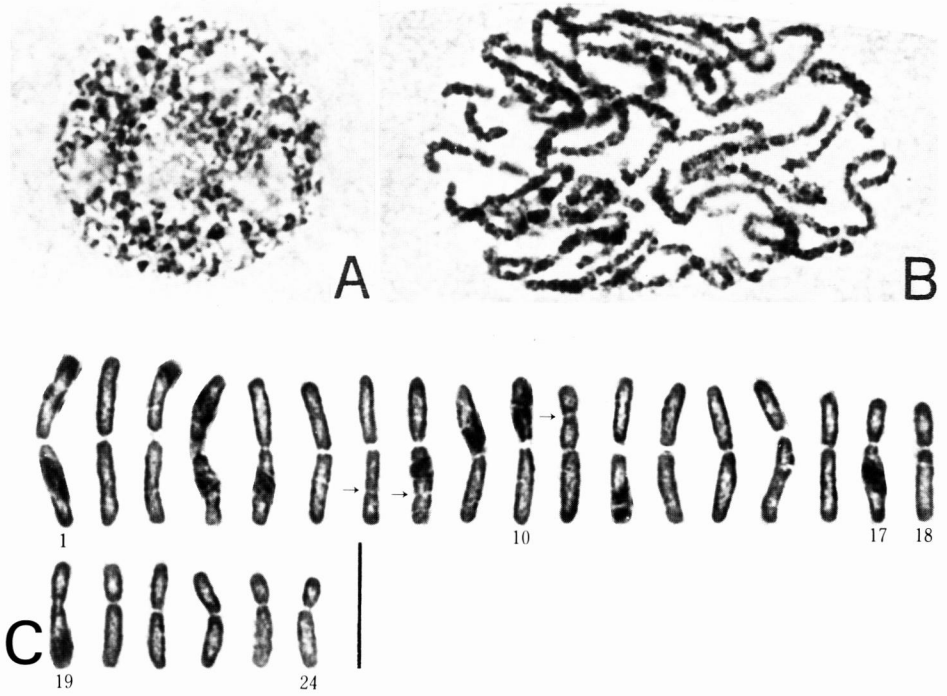

Fig. 30. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea polita* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

regions of several pairs of chromosomes, but their locations were not determined during the course of observation.

31. *Picea asperata* Mast., 2n=24, Fig. 31

Seeds obtained from the People's Republic of China (Table 1) were germinated and their root tips were used for cytological observation. The materials showed the chromosome number of 2n=24, which verified the previous count reported by Santamour (1960).

The chromosomes at interphase (Fig. 31A) and mitotic prophase (Fig. 31B) were similar in karyomorphology to those in *P. abies* and were categorized to be the complex chromocenter type and the continuous type, respectively. A degradation in length of chromosomes at metaphase was observed from 14.5–7.0 μm in the karyotype. A pair of the longest chromosomes and four pairs of small chromosomes were easily distinguished. Most of the chromosomes showed their centromeres at median regions, while three pairs of shorter chromosomes (the 9th, 10th, 12th pairs) showed their centromeres at submedian regions (Fig. 31C). Secondary constrictions were observed at interstitial regions of one of the arms on two pairs of metacentric chromosomes (the 2nd, 3rd).

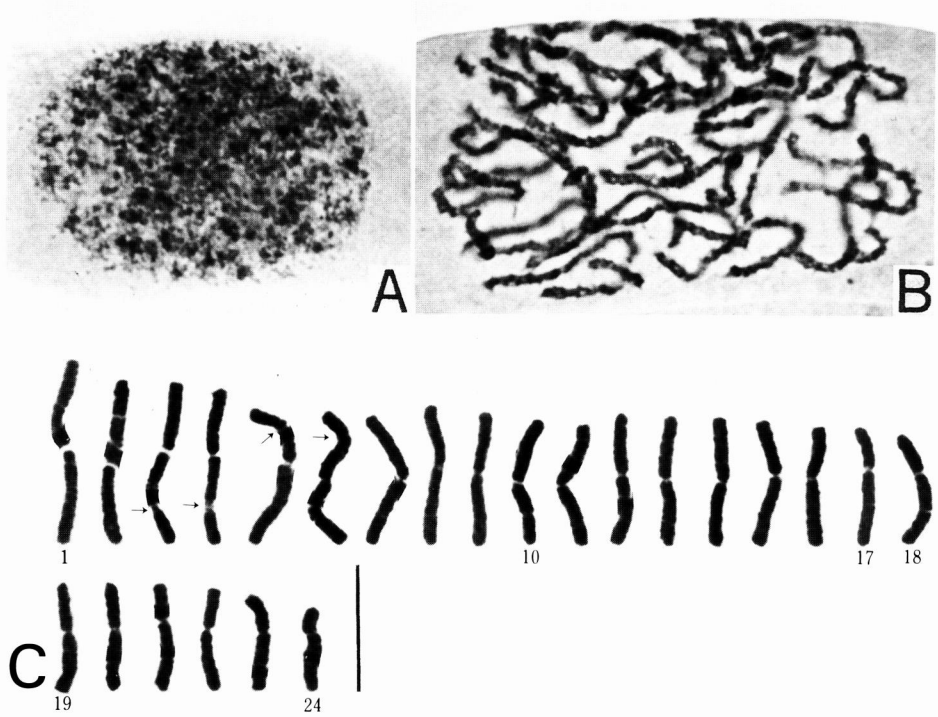

Fig. 31. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea asperata* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

32. *Picea smithiana* (Wall.) Boiss., 2n=24, Fig. 32.

Seeds of one origin (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number for this species was counted to be 2n=24 in all preparations, which verified the previous count reported by Mehra & Khoshoo (1956) and Santamour (1960).

The chromosomes at interphase (Fig. 32A) and mitotic prophase (Fig. 32B) were of the complex chromocenter type and the continuous type, respectively, similar to those in *P. abies*. The lengths of the metaphase chromosomes of the complement indicated a degradation from 13.8–7.4 μm. A pair of the longest chromosomes and four pairs of shorter chromosomes were easily distinguished. The majority of the chromosomes had a centromere at median region while two pairs of shorter chromosomes (the 9th, 12th pairs) had centromeres at submedian regions (Fig. 32C). Secondary constrictions were observed at interstitial regions of several chromosomes. The karyotype at metaphase is essentially similar to that reported by Mehra & Khoshoo (1956).

33. *Picea omorika* (Pancić) Bolle, 2n=24, Fig. 33.

Seeds collected from two origins (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number for this species was 2n=24,

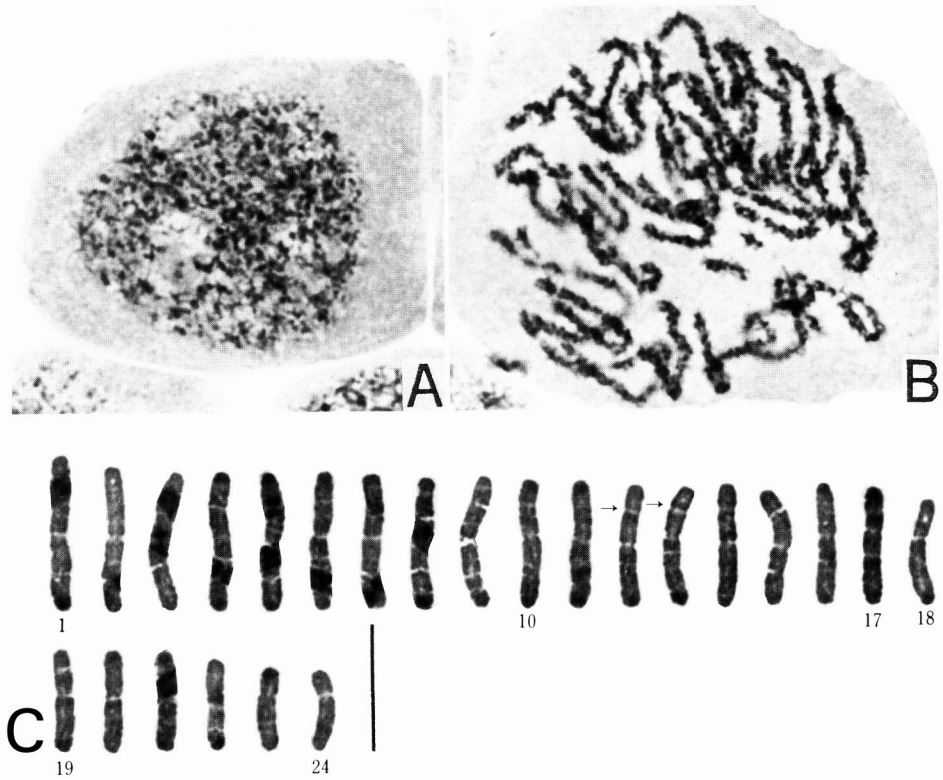

Fig. 32. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea smithiana* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

verified the previous count reported by Santamour (1960).

The chromosomes at interphase (Fig. 33A) and mitotic prophase (Fig. 33B) were categorized to be the complex chromocenter type and the continuous type, respectively, which were similar to those in *P. abies*. A gradual decrease in length from the longest chromosomes of 13.8 μm to the shortest chromosome of 7.0 μm was observed. A pair of the longest chromosomes and four pairs of short chromosomes were easily distinguished. Most of the chromosomes were metacentric, two pairs (the 4th and 9th) of chromosomes meta-submetacentric and the 12th pair of chromosomes submetacentric (Fig. 33C). Secondary constrictions were occasionally observed at interstitial regions of one of the arms on several chromosomes.

34. *Picea sitchensis* (Bong.) Carr., 2n=24, Fig. 34

Seeds collected from two localities in Canada (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number was counted to be 2n=24 in all preparations, which verified the previous counts reported by Burley (1965), Moir & Fox (1972, 1977) and Teoh & Rees (1977).

The interphase (Fig. 34A) and mitotic prophase chromosomes (Fig. 34B) showed

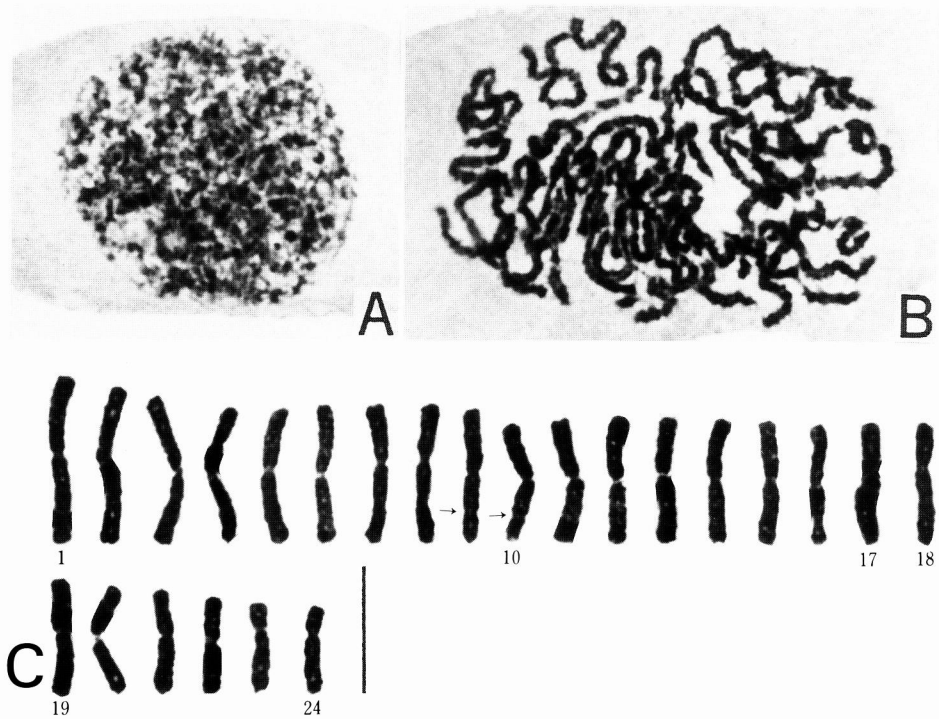

Fig. 33. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea omorika* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

similarity in karyomorphology to those in *P. abies* and were categorized to be the complex chromocenter type and the continuous type, respectively. The lengths of the chromosomes in the complement at metaphase varied gradually from 14.6–7.9 μm. A pair of the longest chromosomes and four pairs of short chromosomes were easily distinguished. The majority of the chromosomes had a centromere at median region while three pairs of shorter chromosomes (the 9th, 10th, 12th pairs) had their centromeres at submedian regions (Fig. 34C). Secondary constriction was observed constantly at interstitial region of one of the arms of the 3rd pair of chromosomes and occasionally of several other chromosomes. The karyotype at mitotic metaphase is generally similar to that reported by Burley (1965) and Moir & Fox (1972, 1977) with exception of presence and location of secondary constriction.

35. *Picea jezoensis* (Sieb. & Zucc.) Carr., 2n=24, Fig. 35 (Japanese name : Ezo-matsu)

Seeds collected from two localities in Hokkaido, Japan (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number of 2n=24 was counted in all preparations, which verified the previous count reported by Santamour (1960).

The chromosomes at interphase (Fig. 35A) and mitotic prophase (Fig. 35B) were classified as the complex chromocenter type and the continuous type, respectively, similar

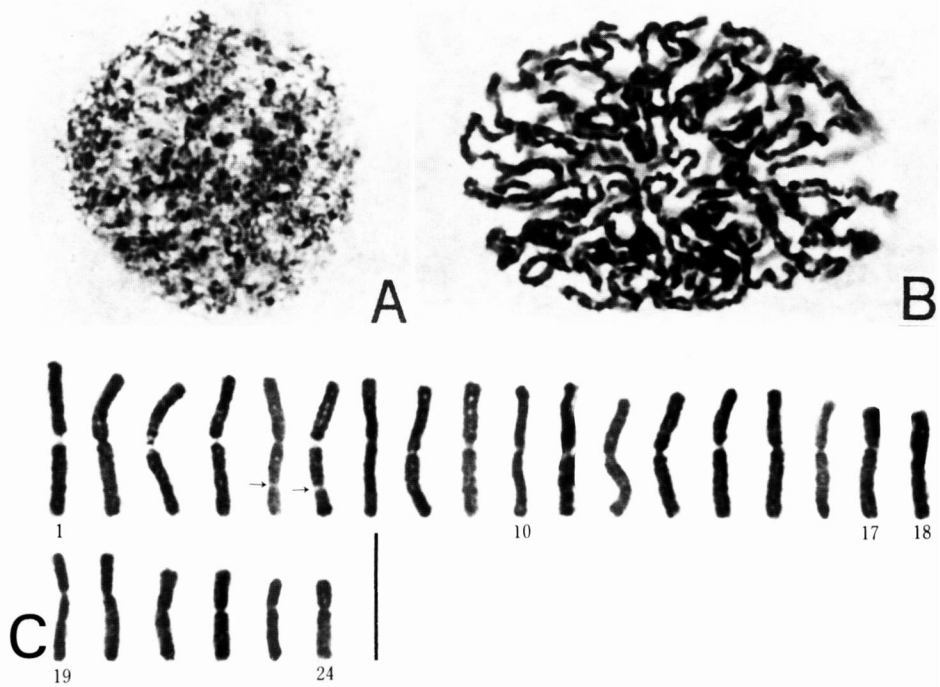

Fig. 34. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea sitchensis* (2n = 24). Bar indicates 10 μm and arrows indicate secondary constrictions.

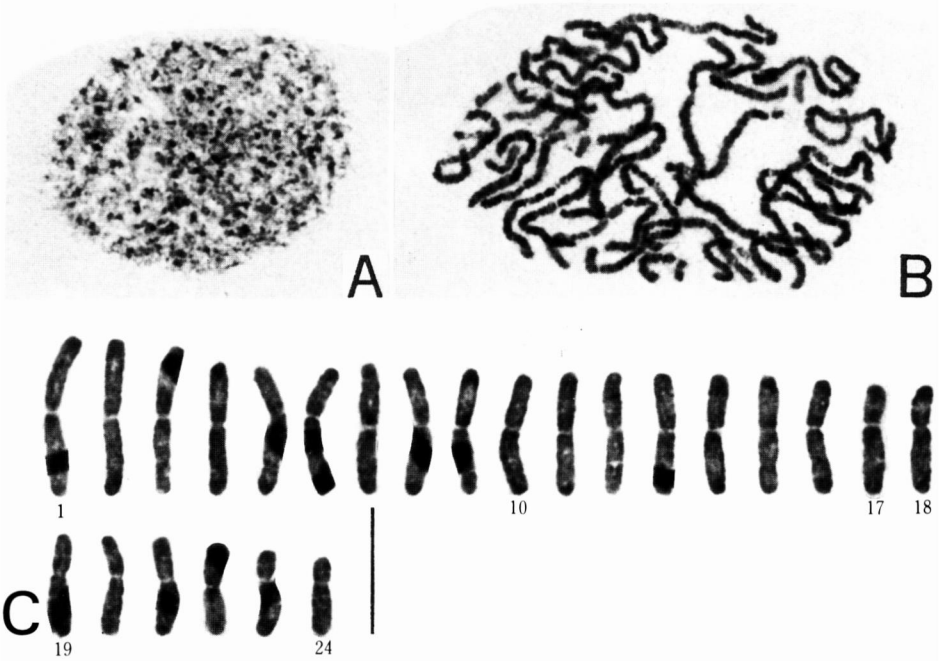

Fig. 35. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea jezoensis* (2n = 24). Bar indicates 10 μm.

to those in *P. abies*. The chromosome complement indicated a degradation in chromosome length from the longest (11.8 μm) to the shortest (6.8 μm) chromosomes. A pair of the longest chromosomes and four pairs of short chromosomes were easily distinguished. Most of the chromosomes in each complement showed their centromeres at median regions excepting for the 3rd and 10th pairs of chromosomes showed their centromeres at median-submedian regions, and two pairs of shorter chromosomes (the 9th, 12th pairs) their centromeres at submedian regions (Fig. 35C). Secondary constrictions were frequently observed at interstitial regions of one of the arms on several pairs of chromosomes.

36. *Picea jezoensis* var. *hondoensis* (Mayr) Rehd., 2n=24, Fig. 36 (Japanese name : Tō-hi)

Seeds collected from two localities in Honsyu, Japan (Table 1) were germinated and their root tips were used for cytological observation. All materials observed showed the chromosome number of 2n=24, which verified the previous count reported by Santamour (1960).

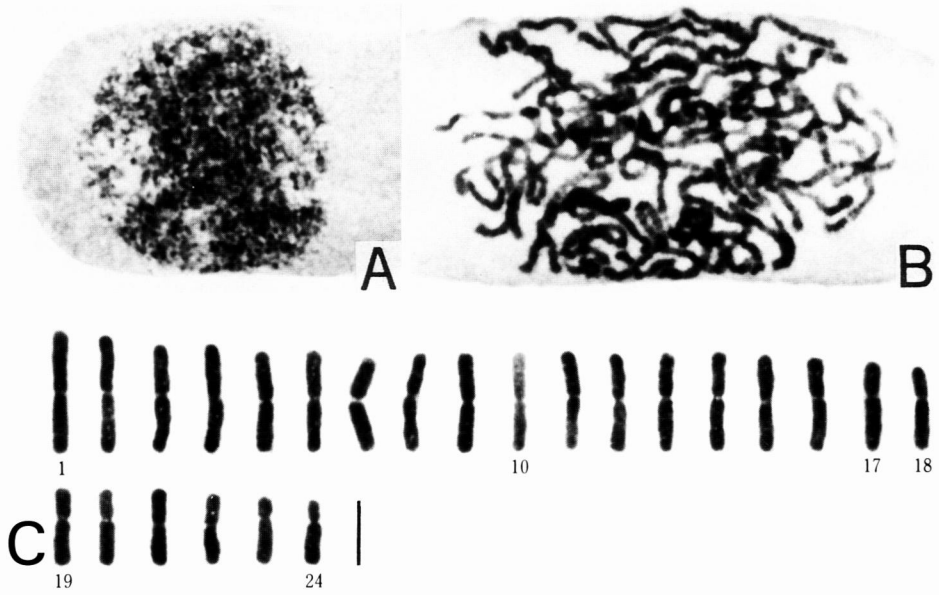

Fig. 36. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Picea jezoensis* var. *hondoensis* (2n=24). Bar indicates 5 μm.

The chromosomes at interphase (Fig. 36A) and mitotic prophase (Fig. 36B) were similar in karyomorphology to those in *P. jezoensis* and were categorized to be the complex chromocenter type and the continuous type, respectively. A gradual decrease in length from the longest (13.2 μm) to the shortest (6.6 μm) chromosomes at metaphase was observed. Positions of the centromeres of those chromosomes were similar to those observed in *P. jezoensis* (Fig. 36C). Secondary constrictions were observed at interstitial regions of one of the arms on several pairs of chromosomes.

37. *Pseudolarix kaempferi* (Ldl.) Gord., 2n=44, Table 8 and Fig. 37

Five plants were cytologically investigated. They showed the chromosome number of 2n=44, which confirmed some previous reports (Sax & Sax 1933, Mergen 1961) but did not support the reports of n=12 (Miyake & Yasui 1911) and 2n=24 (Durrieu-Vabre 1961).

The chromosomes at interphase formed fine threads, many small chromomeric granules, several chromocentral bodies. The several heteropycnotic bodies were spherical with a diameter of about 1.0 μm and were located at part of nucleus (Fig. 37A). Number of heteropycnotic bodies was less than that in the other species of the Pinaceae. One to four nucleoli were observed in every nucleus. Morphology of the chromosomes at interphase is categorized to be the complex chromocenter type.

The chromosomes at mitotic prophase were condensed homogeneously (Fig. 37B) and the condensation pattern was considered to be the continuous type.

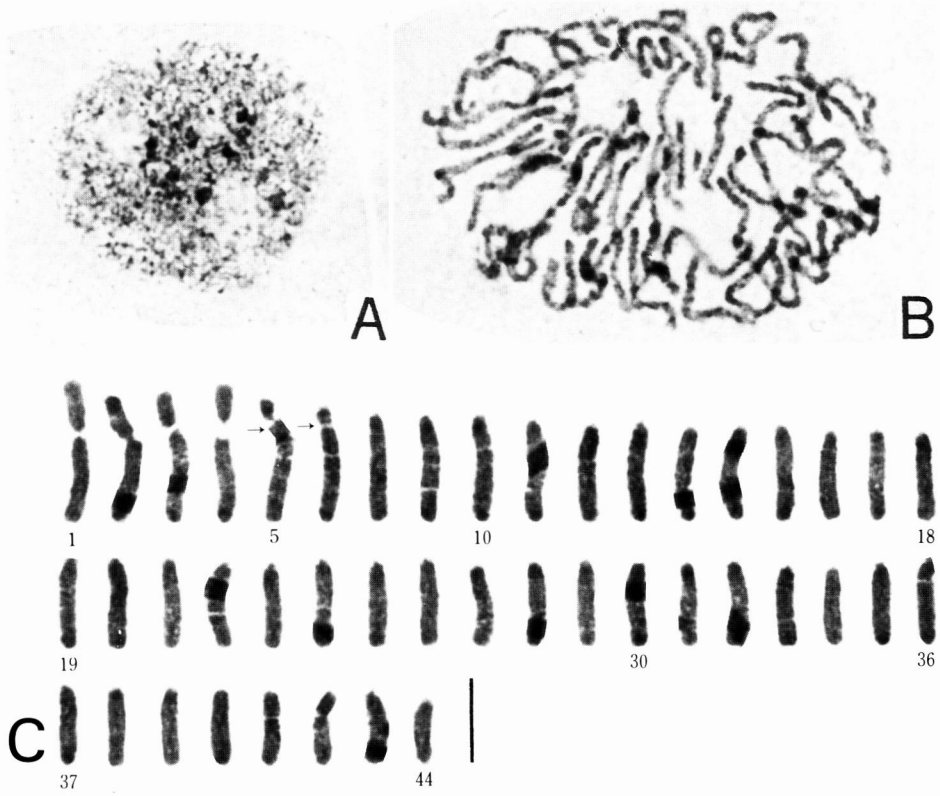

Fig. 37. Photomicrograph of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pseudolarix kaempferi* (2n=44). Bar indicates 5 μm and arrows indicate secondary constrictions.

The chromosomes in each complement at mitotic metaphase varied in length from 7.1–3.5 μm. Four chromosomes were larger than the other and medium-sized. The other chromosomes were small and decreased gradually in length. The chromosome complement showed bimodal variation in length. Two pairs of larger chromosomes contained their cen-

tromeres at submedian regions and all small chromosomes their centromeres at terminal regions (Table 8, Fig. 37C). The short arms of the telocentric chromosomes were too small to measure their lengths. When those chromosomes got shortened weakly, their minute arms apparently visible. Since telocentric chromosomes dominated in the chromosome complement, the karyotype of this species was the most asymmetric among the members of the Pinaceae. The figure of the karyotype at mitotic metaphase were basically similar to that reported by Sax & Sax (1933) and Mergen (1961). Secondary constriction was observed at proximal region of the long arm of the 3rd pair of chromosomes. Small constrictions were sometimes observed on several chromosomes, also.

38. *Larix potaninii* Batal., 2n=24, Table 9 and Fig. 38

Seeds collected from two localities in the People's Republic of China (Table 1) were germinated and their root tips were used for cytological investigation. Twenty-four seedlings exhibited the chromosome number of 2n=24, which was reported here for the first time.

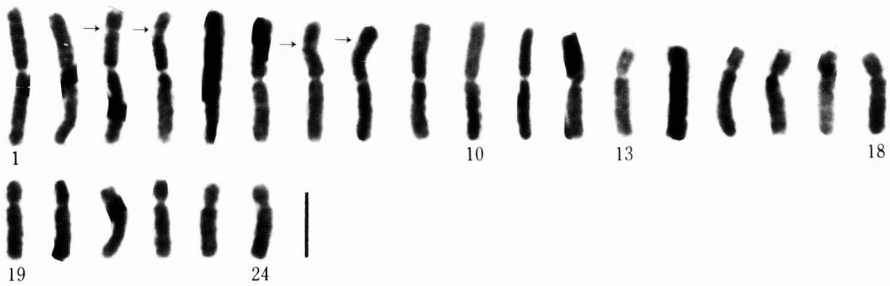

Fig. 38. Photomicrograph of chromosomes at mitotic metaphase in the root tip cells of *Larix potaninii* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

The chromosomes at interphase formed 10–20 heteropycnotic bodies and homogeneously dispersed many chromomeric granules and fibrous chromatin threads. Morphology of the chromosomes at interphase was categorized to be the complex chromocenter type. The chromosomes at mitotic prophase condensed homogeneously along the long axis, and their condensing pattern was categorized to be the continuous type.

Since the mitotic metaphase complement displayed that a half of chromosomes in number was large-sized and the other half was medium-sized, formed a bimodal variation in length. The large-sized chromosomes varied gradually in length from 11.0–8.8 μm while the medium-sized chromosomes varied gradually in length from 7.4–5.8 μm. All of the large chromosomes were observed to be metacentric, and the shortest one (the 6th pair) among the large chromosomes was somewhat symmetric. The medium-sized chromosomes showed their centromeres at submedian regions (Fig. 38). Secondary constrictions appeared at interstitial regions of short arm of two pairs of metacentric chromosomes (the 2nd 4th pairs).

39. *Larix occidentalis* Nutt., 2n=24, Fig. 39

Seeds collected in Flathead Valley, British Columbia, Canada were germinated and their root tips were used for cytological investigation. The mitotic metaphase cell contained the chromosome number of 2n=24. This number confirmed the previous count (Sax & Sax 1933) but did not support the tetraploid number (Knaben 1953).

The chromosomes at interphase formed 10–20 heteropycnotic bodies and homogeneously dispersed many chromomeric granules and fibrous chromatin threads (Fig. 39A). Thus, morphology of the chromosomes at interphase is categorized to be the complex chromocenter type. One to four nucleoli presented in each nucleus. The chromosomes at mitotic prophase condensed homogeneously along the long axis (Fig. 39B). Thus, such condensing pattern of the prophase chromosomes is categorized to be the continuous type.

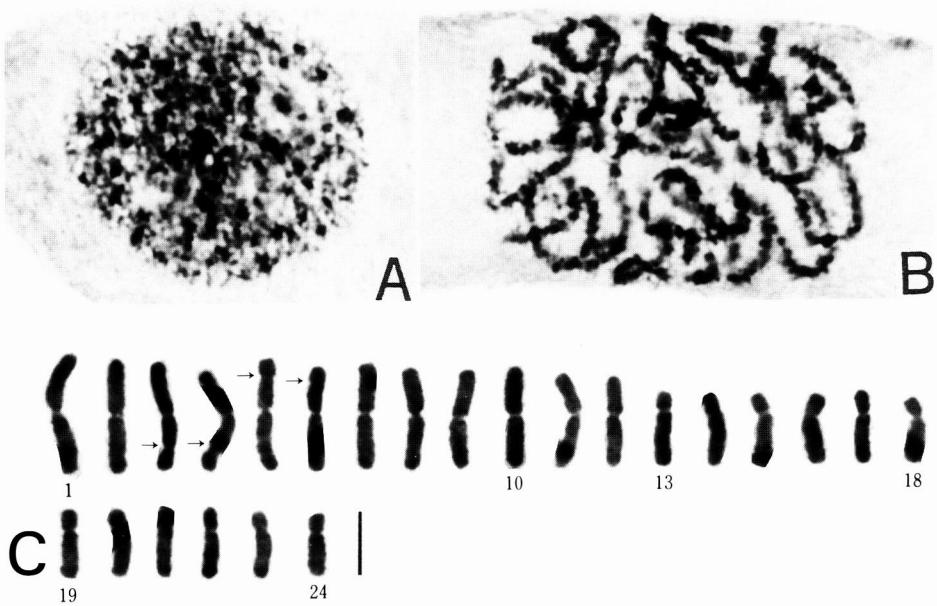

Fig. 39. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Larix occidentalis* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

Since the mitotic metaphase complement displayed that a half of the chromosomes in number was large and the other half was medium-sized, it performed a bimodal variation in length, same as that in *L. potaninii*; The long chromosomes varied in length from 10.0–7.3 μm and the medium-sized chromosomes from 6.2–4.9 μm. All of the large chromosomes were observed to be metacentric but the smallest one of the large chromosomes (the 6th) was somewhat asymmetric. The medium-sized chromosomes possessed their centromere at submedian regions (Fig. 39C). Secondary constrictions appeared at interstitial regions of one of the arms of two pairs of metacentric chromosomes (the 2 and 3th pairs).

40. *Larix leptolepis* (Sieb. & Zucc.) Gord., 2n=24, Fig. 40 (Japanese name : Kara-matsu)

Seeds collected from four localities in Japan (Table 1) were germinated and their root tips were used for cytological investigation. All plants studied showed the chromosome number of 2n=24, which confirmed the previous counts (Ishikawa 1902, Sax 1932, Sax & Sax 1933, Price *et al.* 1973 and Zhang *et al.* 1985).

The chromosomes at interphase (Fig. 40A) and mitotic prophase (Fig. 40B) were similar to those of *L. occidentalis* and were categorized to be the complex chromocenter type and the continuous type, respectively. One to four nucleoli were observed in each nucleus.

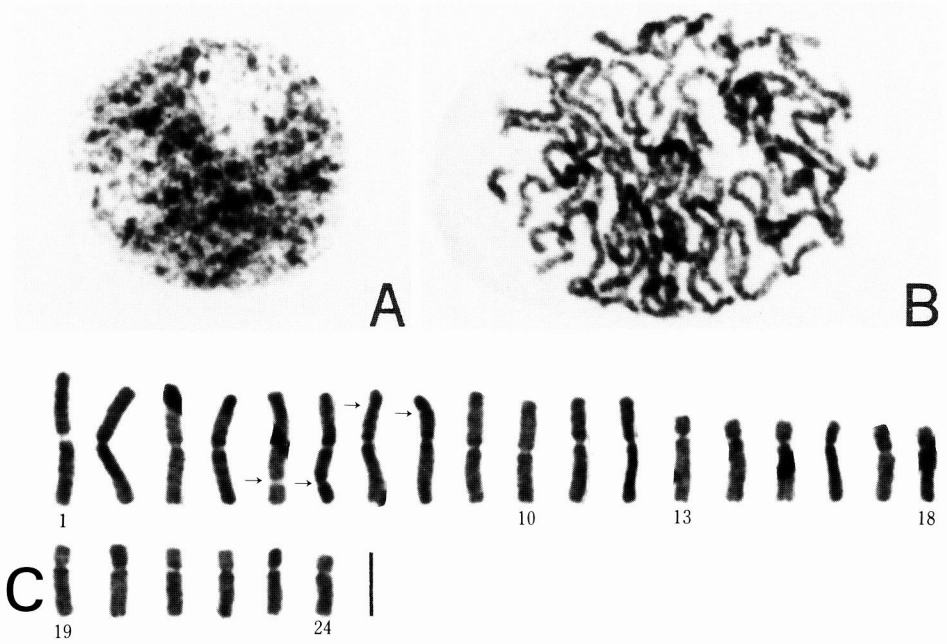

Fig. 40. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Larix leptolepis* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

Among the mitotic metaphase chromosomes of the complement a half in number was larger than the other half. Thus, the chromosome complement showed a bimodal variation in length, same as that observed in *L. potaninii*. The large chromosomes varied in length from 10.6-8.6 μm and the medium-sized chromosomes from 7.0-5.1 μm. All of the long chromosomes were observed to be metacentric excepting for the shortest pair of chromosomes (the 6th) is somewhat asymmetric. The medium-sized chromosomes possessed their centromeres at submedian regions (Fig. 40C). Secondary constrictions appeared at interstitial regions of one of the arms of two pairs of metacentric chromosomes (the 3 and 4th pairs). Karyomorphological feature at metaphase in this species is generally similar to that reported by Zhang *et al.* (1985).

41. *Larix gmelinii* (Rupr.) Kuzeneva, 2n=24, Fig. 41A

Seeds collected at two localities in the People's Republic China (Table 1) were germinated and their root tips were used for cytological investigation. All plants studied exhibited the chromosome number of 2n=24, which confirmed the previous counts (Kruklis 1970, Zhang *et al.* 1985 and Tong & Hao 1986).

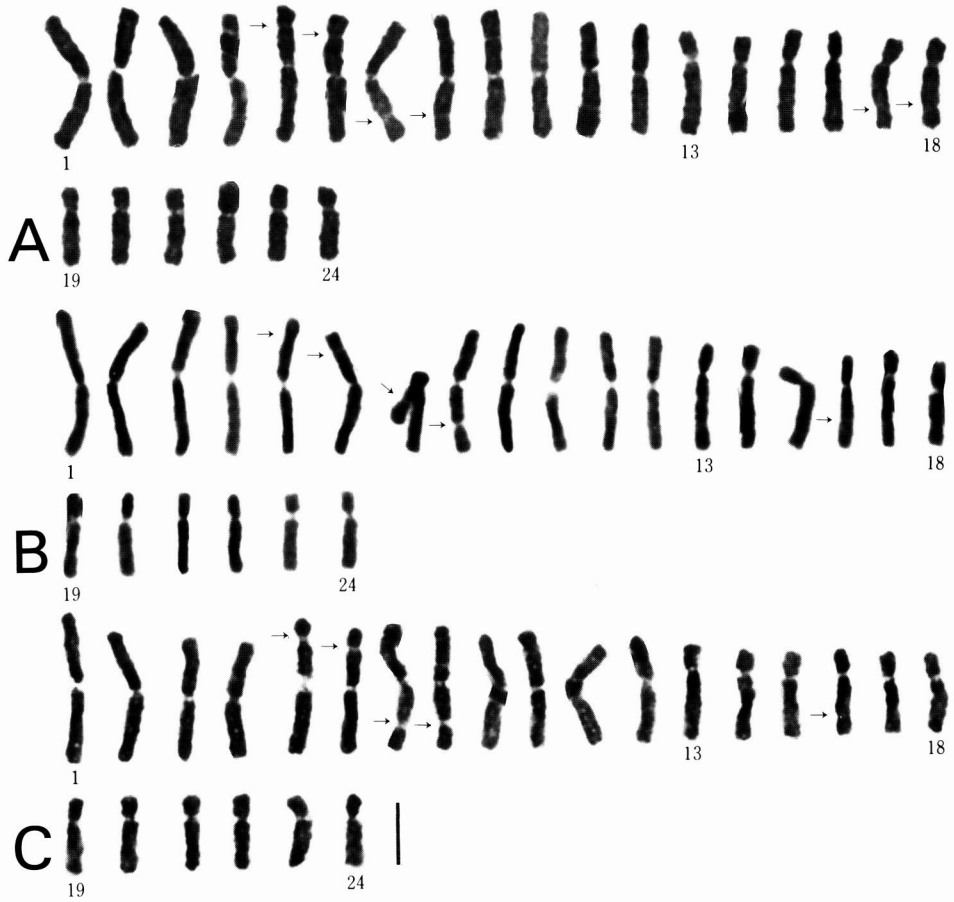

Fig. 41. Photomicrographs of chromosomes at mitotic metaphase in the root tip cells of *Larix gmelinii* (2n=24) (A), *L. gmelinii* var. *japonica* (2n=24) (B) and *L. gmelinii* var. *principis-rupprechtii* (2n=24) (C). Bar indicates 5 μm and arrows indicate secondary constrictions.

The chromosomes at interphase and mitotic prophase were similar in karyomorphology to those of *L. occidentalis*. The morphology of chromosomes at interphase and prophase is categorized to be the complex chromocenter type and the continuous type, respectively. One to six nucleoli were presented in each nucleus. Among the mitotic metaphase chromosomes of the complement a half in number was large and the other half was medium-sized. Thus, the chromosome complement showed bimodal variation in length, same as that observed in *L. potaninii*. The large chromosomes varied in length from 11.6–

8.9 μm and the medium-sized chromosomes from 8.5-5.9 μm. All of the large chromosomes were observed to be metacentric excepting for the shortest one pair (the 6th) of chromosomes was somewhat asymmetric. All of the medium-sized chromosomes were submetacentric (Fig. 41A). Secondary constrictions appeared at interstitial regions of one of the arms of two pairs of chromosomes (the 3rd and 4th pairs) and at distally interstitial region of long arm of the 10th pairs of submetacentric chromosomes. Karyomorphological feature at metaphase is essentially similar to that reported by Kruklis (1970), Zhang *et al.* (1985) and Tong & Hao (1986).

42. *Larix gmelinii* var. *japonica* (Maxim. ex Regel) Pilg., 2n=24, Fig. 41B (Japanese name : Gui-matsu)

Seeds collected in Yakutskaya, U.S.S.R. (Table 1) were germinated and their root tips were used for cytological investigation. The chromosome number of 2n=24 for this species is here reported for the first time.

The chromosomes at interphase and mitotic prophase were observed to be very similar to those of *L. occidentalis*. Karyomorphology at interphase and prophase was categorized to be the complex chromocenter type and the continuous type, respectively. Maximum numbers of nucleoli among plants varied from 4-6. Karyomorphology at metaphase was similar to that of *L. gmelinii* (Fig. 41B). Secondary constrictions appeared constantly at interstitial regions of one of the arms of two pairs of metacentric chromosomes. Occurrence of the secondary constrictions of the submetacentric chromosomes was infrequent among the plants.

43. *Larix gmelinii* var. *principis-rupprechtii* (Mayr) Pilg., 2n=24, Fig. 41C

Seeds collected in two localities in the People's Republic of China (Table 1) were germinated and their root tips were used for cytological investigation. The chromosome number for this species was counted to be 2n=24, which was same as that counted by Zhang *et al.* (1985).

The chromosomes at interphase and mitotic prophase were observed to be very similar to those of *L. gmelinii*. Karyomorphology at mitotic interphase and prophase was categorized to be the complex chromocenter type and the continuous type, respectively. Maximum number of nucleoli among the plants varied from 4-6. Karyomorphology at metaphase was similar to that of *L. gmelinii* (Fig. 41C). Four to six secondary constrictions were observed in similar status appeared in *L. gmelinii* var. *japonica*. The karyotype is essentially similar to that reported by Zhang *et al.* (1985) with differences in presence of secondary constriction.

44. *Larix decidua* Mill., 2n=24, Fig. 42

Seeds collected in four localities (Table 1) were germinated and their root tips were used for cytological investigation. The chromosome number of this species was 2n=24 in

all plants, which confirmed the previous counts (Sax & Sax 1933, Knaben 1953, Simak 1962) but did not support a tetraploid count (Christiansen 1950).

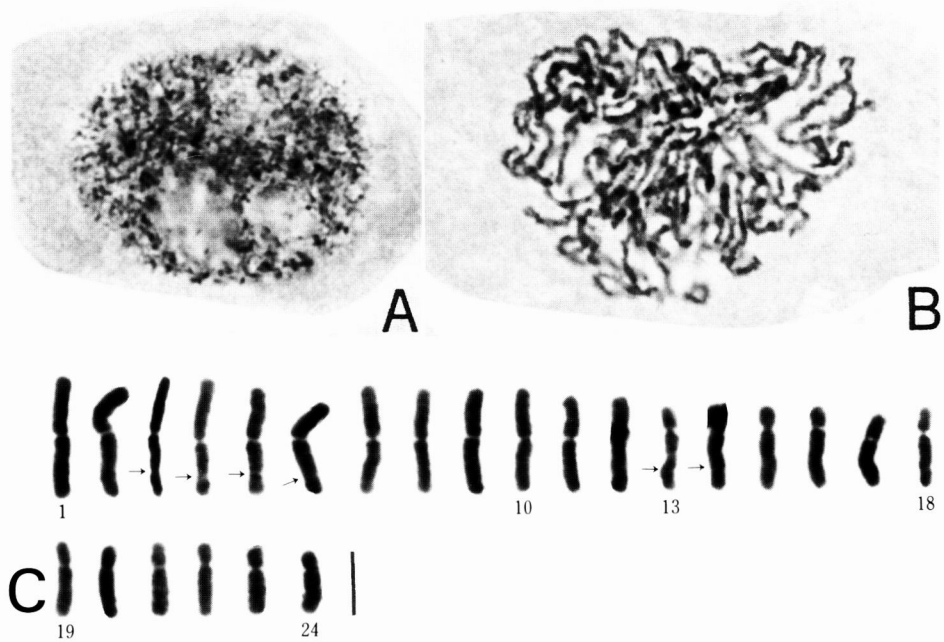

Fig. 42. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Larix decidua* (2n = 24). Bar indicates 5 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 42A) and mitotic prophase (Fig. 42B) were found to be similar in karyomorphology to those of *L. occidentalis* and were categorized to be the complex chromocenter type and the continuous type, respectively. The nucleus contained up to six nucleoli. A half of chromosomes of the metaphase complement in number was large-sized while the other half was medium-sized. The chromosome complement showed a bimodal variation in length, same as that observed in *L. potaninii*. The large-sized chromosomes varied in length from 9.9-7.5 μm and the medium-sized chromosomes from 6.9-5.0 μm. All of the large-sized chromosomes were metacentric excepting for a shortest pair among the large-sized chromosomes was somewhat asymmetric. The medium-sized chromosomes possessed their centromeres at submedian regions (Fig. 42C). Secondary constrictions appeared at interstitial regions of one of the arms of two pairs of large metacentric chromosomes (the 2nd and 3th pairs) and at terminally interstitial regions of long arms of the submetacentric chromosomes (the 7th pair). The karyotype at metaphase was similar to that of *L. gmelinii* and generally coincided to that reported by Sax & Sax (1933), Knaben (1953) and Simak (1962) except for number and location of secondary constriction.

45. *Larix laricina* (Duroi) K. Koch., 2n=24, Fig. 43

Seeds collected at two localities in Canada (Table 1) were germinated and their root tips were used for cytological investigation. The chromosome number of 2n=24 was counted in all specimens. This chromosome count that reported by Chandler & Mavrodineanu (1965).

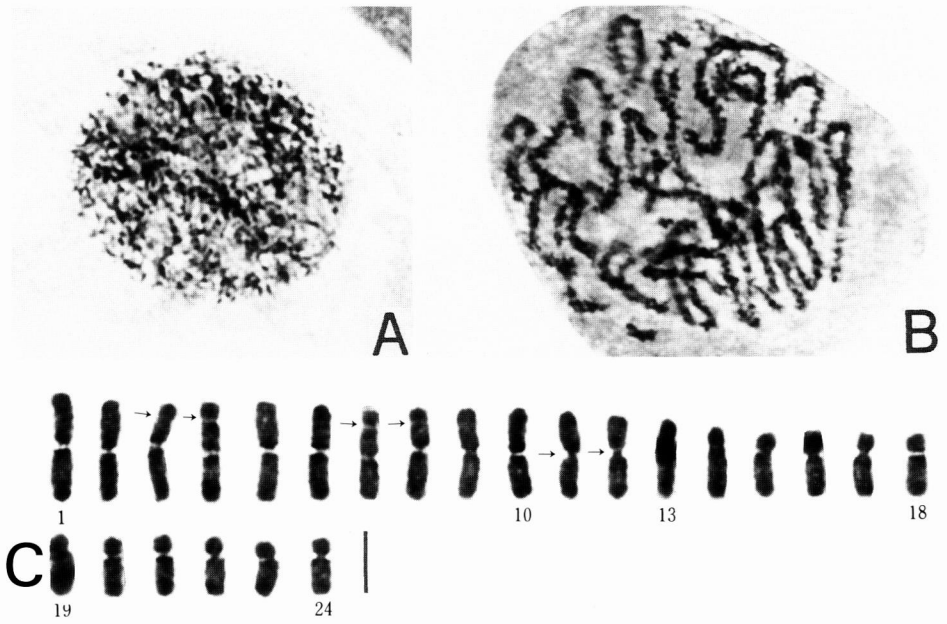

Fig. 43. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Larix laricina* (2n=24). Bar indicates 5 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 43A) and mitotic prophase (Fig. 43B) were found to be similar to those of *Larix* species and were categorized to be the complex chromocenter type and the continuous type, respectively. Maximum six nucleoli in number were found in many nuclei. Among the chromosomes of the metaphase complement a half in number was large and the other half was medium-sized. The chromosome complement showed a bimodal variation in length, same as that observed in *L. potaninii*. The long chromosomes varied in length from 8.8–5.9 μm while the medium-sized chromosomes varied in length from 5.7–4.4 μm. All of the long chromosomes were observed to be metacentric and the shortest one pair among the long chromosomes (the 6th) was somewhat asymmetric. The medium-sized chromosomes exhibited their centromeres at submedian regions (Fig. 43C). Secondary constrictions appeared at interstitial regions of one of the arms of two pairs of metacentric chromosomes (the 2 and 4th pairs) and at proximal region of the 6th pair of metacentric chromosomes.

46. *Cedrus deodara* (Roxb.) Loud., 2n=24, Table 10 and Fig. 44

Three young trees and seedlings (Table 1) were used for chromosomal investigation. They showed the chromosome number of 2n=24, which confirmed the previous counts by Mehra & Khoshoo (1956), Fahmy (1966) and Sugihara (1968).

The chromosomes at interphase formed many chromomeric granules and fibrous chromatin scattering over the nucleus and aggregated to the several spherical heteropycnotic bodies with about 1.5 μm in diameter (Fig. 44A). Karyomorphology at interphase is categorized to be the complex chromocenter type. One to six nucleoli appeared in each nucleus.

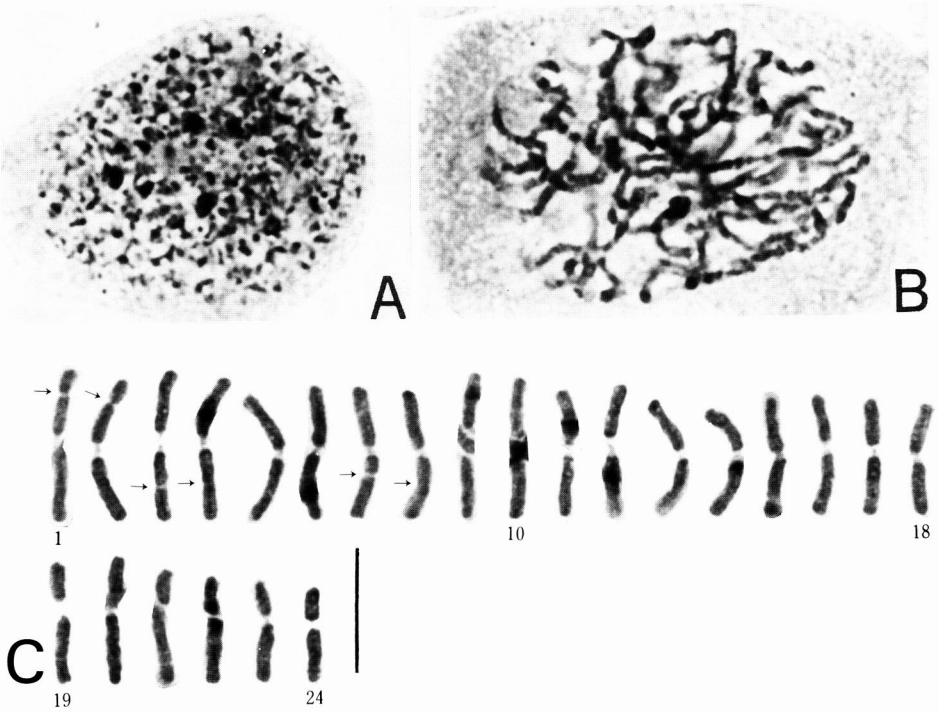

Fig. 44. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Cedrus deodara* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at prophase got condensed homogeneously at any segments (Fig. 44B) and, therefore, were categorized to be the continuous type.

A gradual decrease in size from the longest chromosomes of 11.6 μm to the shortest chromosome of 6.7 μm was observed in the mitotic metaphase chromosome complement. Three pairs of chromosomes were shorter than the others. Most of the chromosomes possessed their centromeres at median regions excepting for three pairs of medium-sized chromosomes (the 10th, 11th, 12th pairs) possessed their centromeres at submedian regions (Table 10, Fig. 44C). The centromeric regions were frequently observed to be elongated, weakly stained regions. Secondary constrictions were observed at interstitial regions of

one of their arms on three pairs (the 1st, 2nd, 4th) of chromosomes. The karyotype at mitotic metaphase was considerably different from that reported by Mehra & Khoshoo (1956).

47. *Pinus strobus* L., 2n=24, Table 11 and Fig. 45

Root tips of six young trees (Table 1) were used for cytological investigation. The chromosome number of 2n=24 was counted in all cells of all plants studied. The chromosome number confirmed the previous counts (Ferguson 1901, 1904, Sax & Sax 1933, Santamour 1960, Saylor 1961, 1983, Kuroki 1969, Price *et al.* 1973, Baranec 1979).

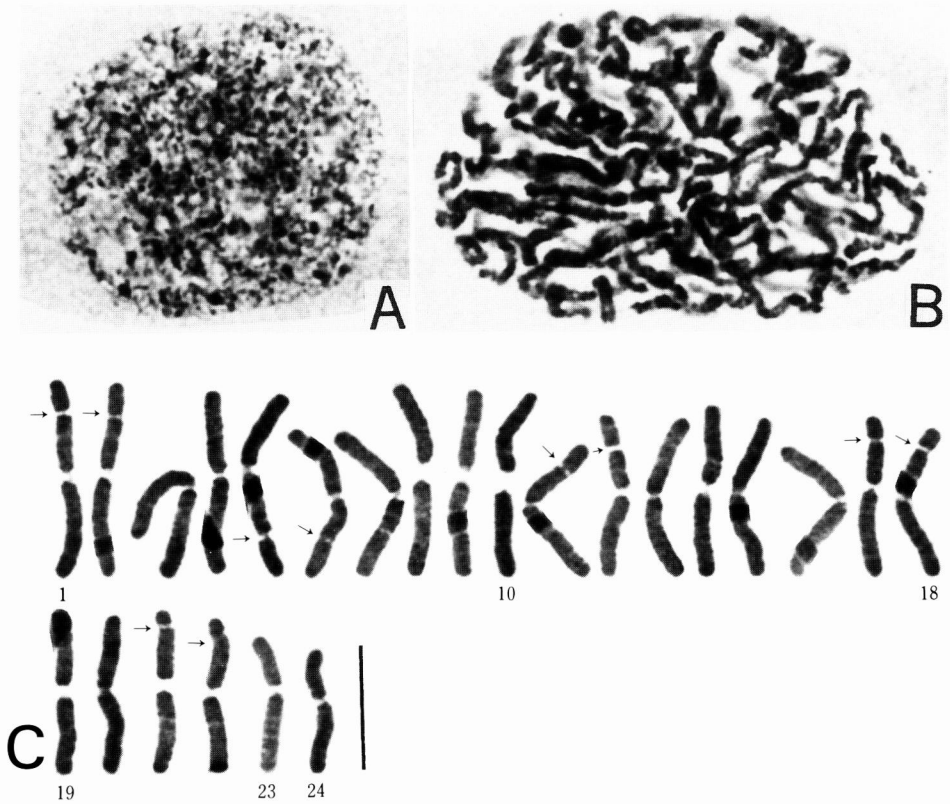

Fig. 45. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus strobus* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase formed 20–30 spherical heteropycnotic bodies with diameter of about 1.2 μm. Some chromatins formed many chromomeric granules and fibrous chromatin threads, which were scattered over nuclear matrix (Fig. 45A). Karyomorphology at interphase is categorized to be the complex chromocenter type. Many nucleoli (4–14 in number) were observed in the interphase nucleus.

The chromosomes at mitotic prophase were observed to be homogeneous threads with

constant width interrupted by centromere, secondary constriction and small constriction (Fig. 45B). The chromosomes were observed to be fragments by squashing process. Thus, karyomorphology at prophase is categorized to be the continuous type. The chromosomes of the complement at mitotic metaphase varied gradually in length from 14.8–9.5 μm. The pair of the shortest chromosomes was distinctly small. Most of the chromosomes possessed their centromeres at median regions excepting for the chromosomes of the smallest pair possessed their centromeres at median–submedian regions (Table 11, Fig. 45C). The chromosome complement is highly symmetrical and homogenerous. Secondary constrictions were observed at interstitial regions of one–side arms on six pairs of chromosomes (the 1st, 4th, 6th, 9th, 11th pairs). Secondary constriction of the 4th pair of chromosomes was located at proximally interstitial region and that of the 11th pair was located at distally interstitial region. Secondary constrictions of the other chromosomes were located at median interstitial regions. The karyotypic characteristics at mitotic metaphase given here supported those reported by Sax & Sax (1933), Saylor (1961, 1983), Kuroki (1969), and Baranec (1979) with exception of secondary constriction which varied in number and location.

48. *Pinus monticola* Dougl., 2n=24, Fig. 46

Three plants at the two–years–old stage were used for cytological observation. The chromosome count for this species showed 2n=24, which confirmed the previous reports by Santamour (1960) and Saylor (1983).

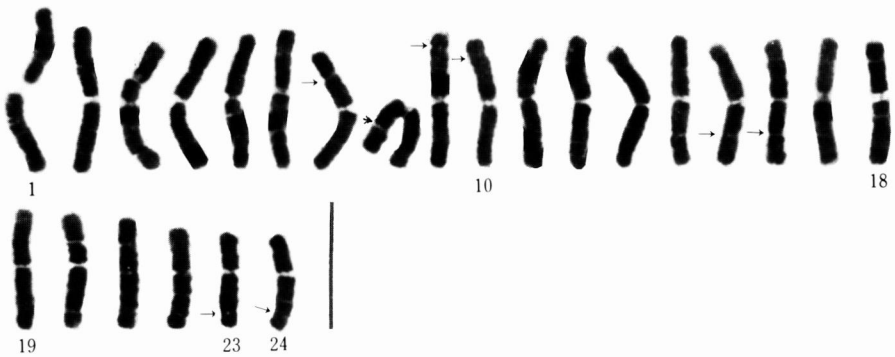

Fig. 46. Photomicrograph of chromosomes at metaphase in the root tip cells of *Pinus monticola* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase and mitotic prophase were similar in karyomorphology to those observed in *P. strobus*. At mitotic metaphase the chromosomes of the complement varied in length gradually from 11.8–8.2 μm. The pair of the shortest chromosomes decreased hastily in length. Centromeres were located at median positions of most chromosomes while those were located at median–submedian region of the pair of the shortest chromosome (Fig. 46). Secondary constrictions were observed at interstitial regions of one of their arms on four pairs of chromosomes (the 4th, 5th, 8th, 12th pairs). The karyotype

at mitotic metaphase was similar to that reported by Saylor (1983).

49. *Pinus peuce* Griseb., 2n=24, Fig. 47

Five of two-year-old plants (Table 1) were used for cytological observation. The chromosome number was counted to be 2n=24 in all plants. This chromosome count confirms the previous reports by Sax & Sax (1933), Geogevitch (1936), Santamour (1960), Sarker (1963) and Saylor (1983).

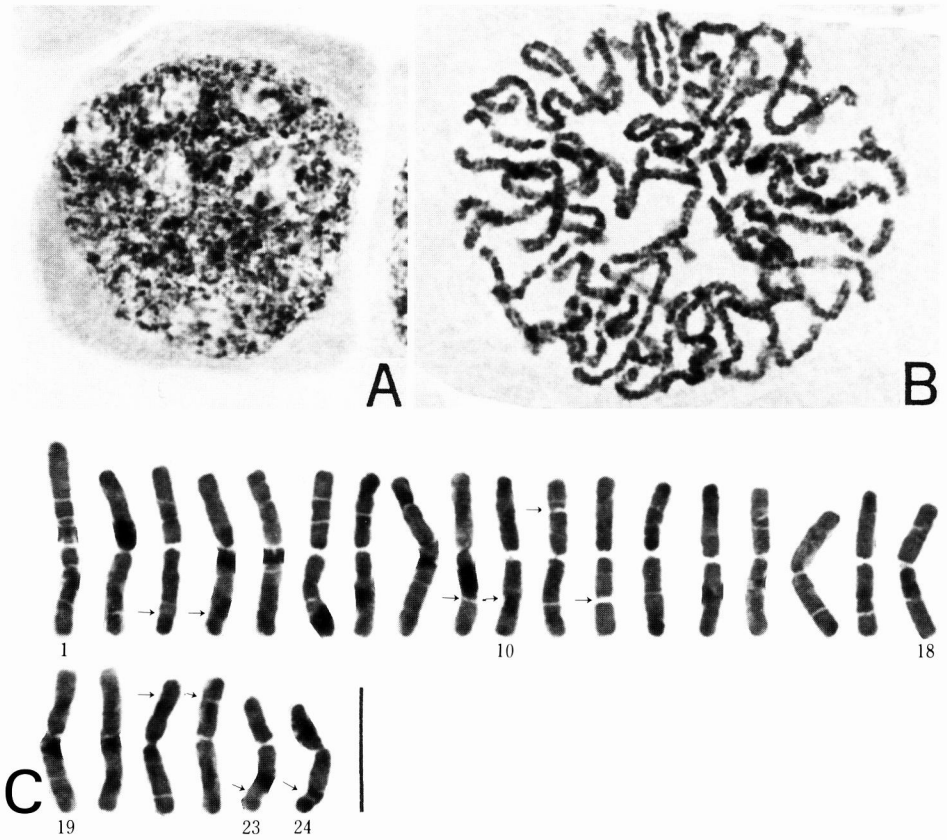

Fig. 47. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus peuce* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 47A) and mitotic prophase (Fig. 47B) were similar in karyomorphology to those in *P. strobus*. They were categorized to be the complex chromocenter type and the continuous type, respectively. The chromosomes in the mitotic metaphase complement varied gradually in length from 11.3–7.0 μm. The pair of the shortest chromosomes decreased apparently in length. The centromeres were located at median regions in most of the chromosomes and those at median-submedian region in the pair of the shortest chromosomes (Fig. 47C). Secondary constrictions were frequently observed at interstitial regions of five pairs (the 1st, 5th, 6th, 12th) of chromosomes. The

karyotype at mitotic metaphase is essentially similar to that reported by Sax & Sax (1933), Sarker (1963) and Saylor (1983) except for number and location of secondary constriction.

50. *Pinus parviflora* Sieb. & Zucc., 2n=24, Fig. 48 (Japanese name : Hime-ko-matsu)

The seeds used were collected in three localities and 12 young trees were collected in two localities, Japan (Table 1). Their root tips were used for cytological observation. The chromosome number of 2n=24 was counted in all plants. This chromosome count confirms that reported by Sax & Sax (1933), Santamour (1960), Toda *et al.* (1982) and Saylor (1983).

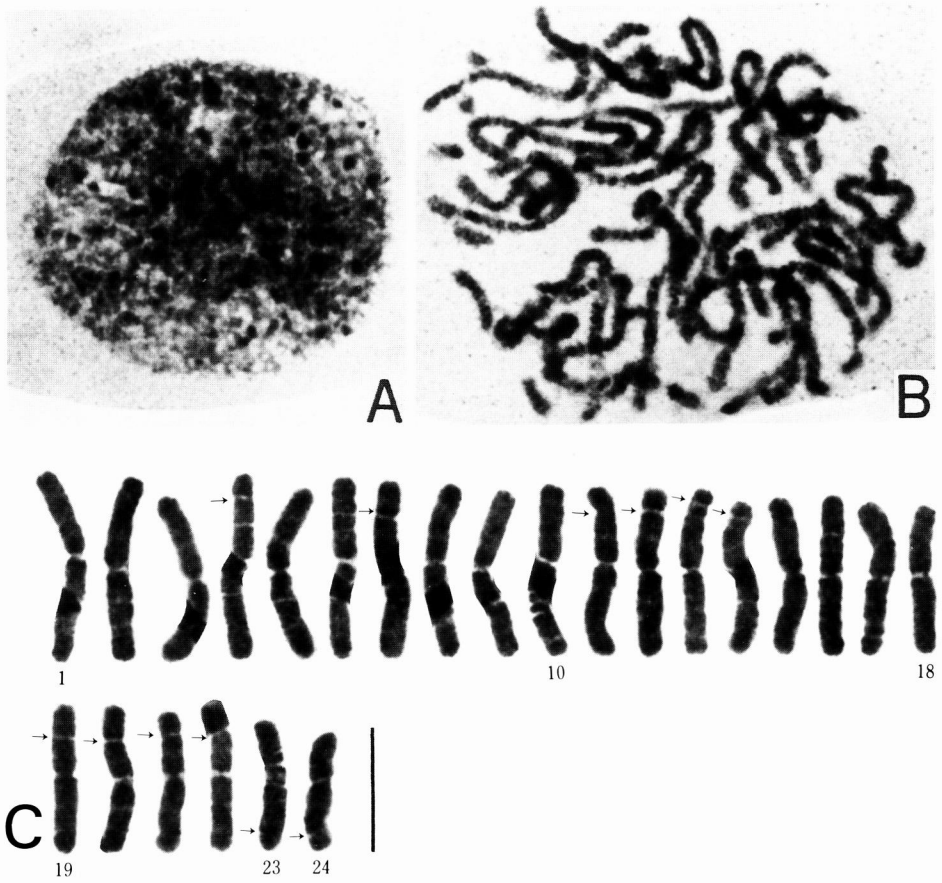

Fig. 48. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus parviflora* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 48A) and mitotic prophase (Fig. 48B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. From the longest chromosome of 14.7 μm to the shortest chromosome of 9.6 μm a degradation in chromosome size was observed in the mitotic metaphase complement. The pair of the shortest chromosomes was

distinctly small. The centromeres were located at median regions of most chromosomes excepting for those at median–submedian region of the pair of the shortest chromosomes (Fig. 48C). The karyotype was highly symmetric. Secondary constrictions were frequently observed at interstitial regions of seven pairs (the 2nd, 4th, 6th, 7th, 10th, 11th, 12th pairs) of metacentric chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Sax & Sax (1933), Toda *et al.* (1982) and Saylor (1983) excepting for number and location of secondary constriction.

51. *Pinus edulis* Engelm., 2n=24, Fig. 49

The seeds used were collected in Coconio, Arizona, U.S.A. and root tips of the germinated seedlings were used for karyomorphological observation. The chromosome number of 2n=24 for this species was counted in all of these plants. This chromosome count confirms the previous documents by Santamour (1960) and Saylor (1983).

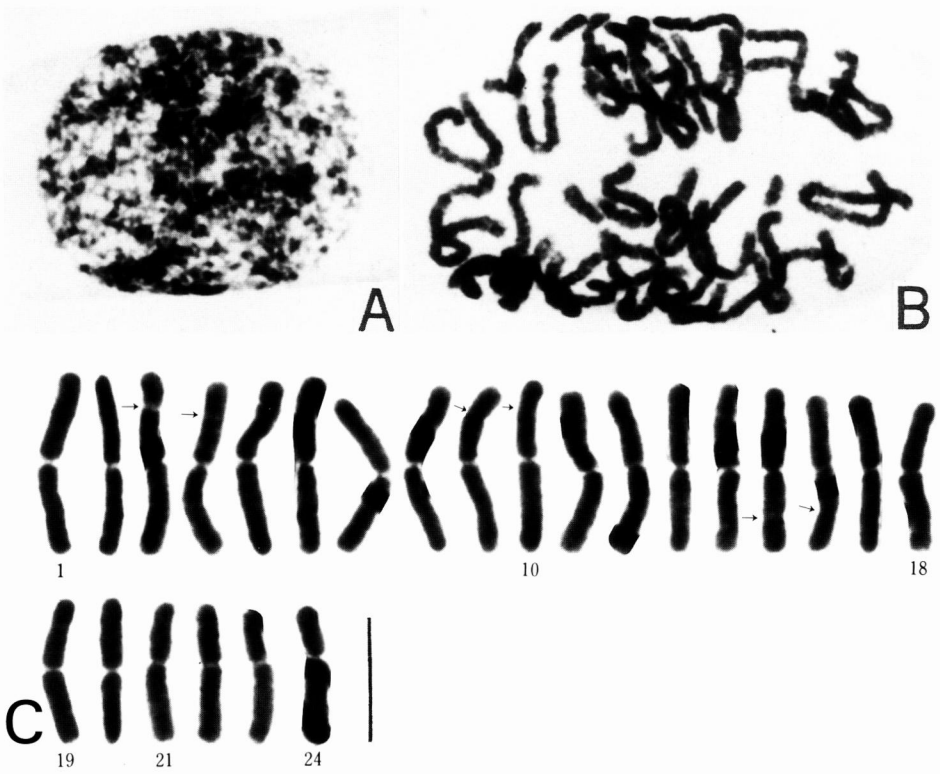

Fig. 49. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus edulis* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 49A) and mitotic prophase (Fig. 49B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase comple-

ment the chromosomes varied gradually in length from 14.6–10.7 μm. Centromeres in most pairs of chromosomes were located at median regions while those in the pair of the shortest chromosomes were located at median–submedian regions (Fig. 49C). The karyotype was highly symmetric. Secondary constrictions were observed at interstitial regions of three pairs (the 2nd, 5th, 8th pairs) of metacentric chromosomes and occasionally on several other chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Saylor (1983) except for number and location of secondary constriction.

52. *Pinus bungeana* Zucc., 2n=24, Fig. 50

A cutting and seeds were obtained from the People's Republic of China (Table 1). Their root tips were used for cytological observation. The chromosome number was counted to be 2n=24 in all plants studied. This chromosome count confirmed the previous reports by Sax & Sax (1933), Santamour (1960), Pan *et al.* (1982), Liu *et al.* (1983) and Saylor (1983).

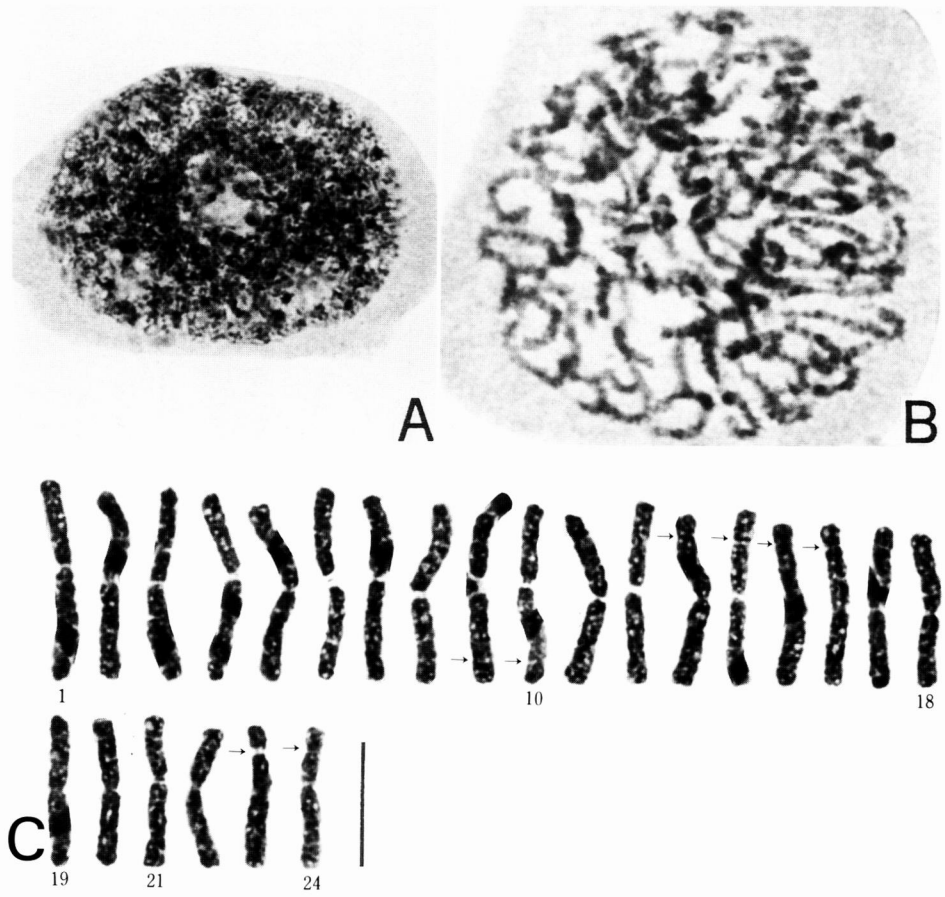

Fig. 50. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus bungeana* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 50A) and mitotic prophase (Fig. 50B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. A gradual decrease in size from the longest chromosomes of 15.9 μm to the shortest chromosome of 10.9 μm was observed in the mitotic metaphase complement. The pair of the shortest chromosomes decreased hastily in length. Centromeres were located at median regions of most of the chromosomes while those were located at median–submedian region in the pair of the shortest chromosomes (Fig. 50C). The karyotype was highly symmetric. Secondary constrictions were frequently observed at interstitial regions of one of arms on four pairs (the 5th, 7th, 8th, 12th) of chromosomes. Small constrictions were frequently observed at interstitial regions of some chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Sax & Sax (1933), Liu *et al.* (1983) and Saylor (1983) except for number and locality of secondary constriction.

53. *Pinus aristata* Engelm., 2n=24, Fig. 51

Seeds (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number for this species was 2n=24, which confirmed the previous

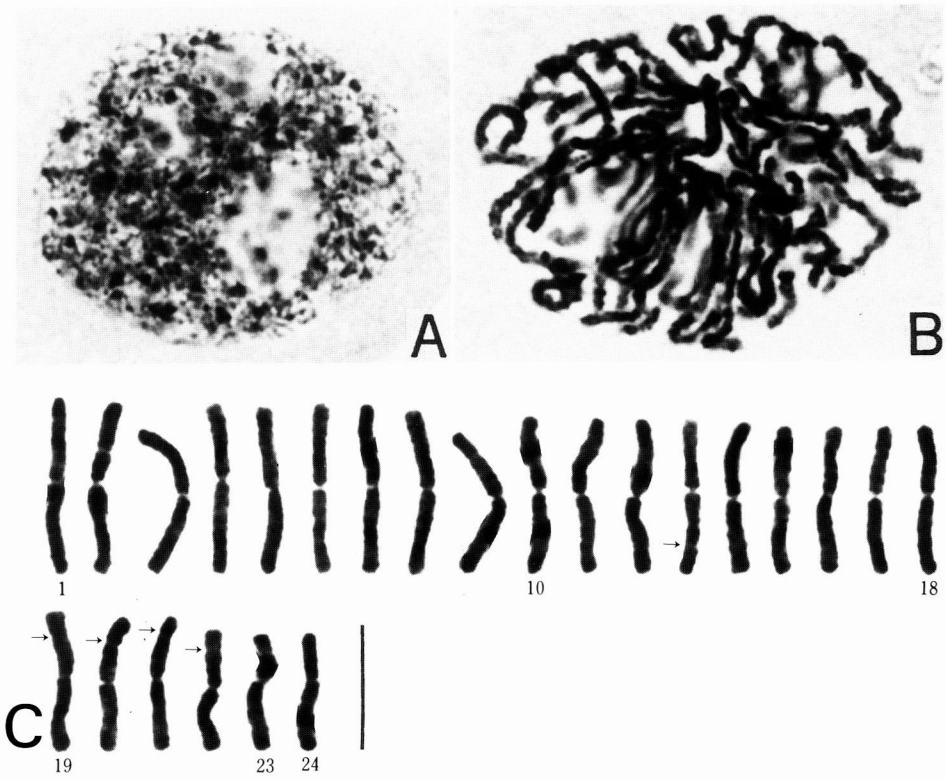

Fig. 51. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus aristata* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

reports by Price *et al.* (1973) and Saylor (1983).

The chromosomes at interphase (Fig. 51A) and mitotic prophase (Fig. 51B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. The chromosomes of the mitotic metaphase complement varied gradually in length from 13.9–9.5 μm. The majority of the chromosomes had a centromere located at median position while the pair of the shortest chromosomes had a centromere at median–submedian position (Fig. 51C). The karyotype was highly symmetric. Secondary constrictions were frequently observed at interstitial regions of one of the arms in three of pairs (the 7th, 10th, 11th) of metacentric chromosomes and occasionally some other chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Saylor (1983) except for number and location of the secondary constriction.

54. *Pinus canariensis* C. Smith, 2n=24, Fig. 52

Seeds obtained in U.S.A. (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number for this species was counted to be 2n=24, which confirmed the previous reports by Mehra & Khoshoo (1956), Pederick (1970)

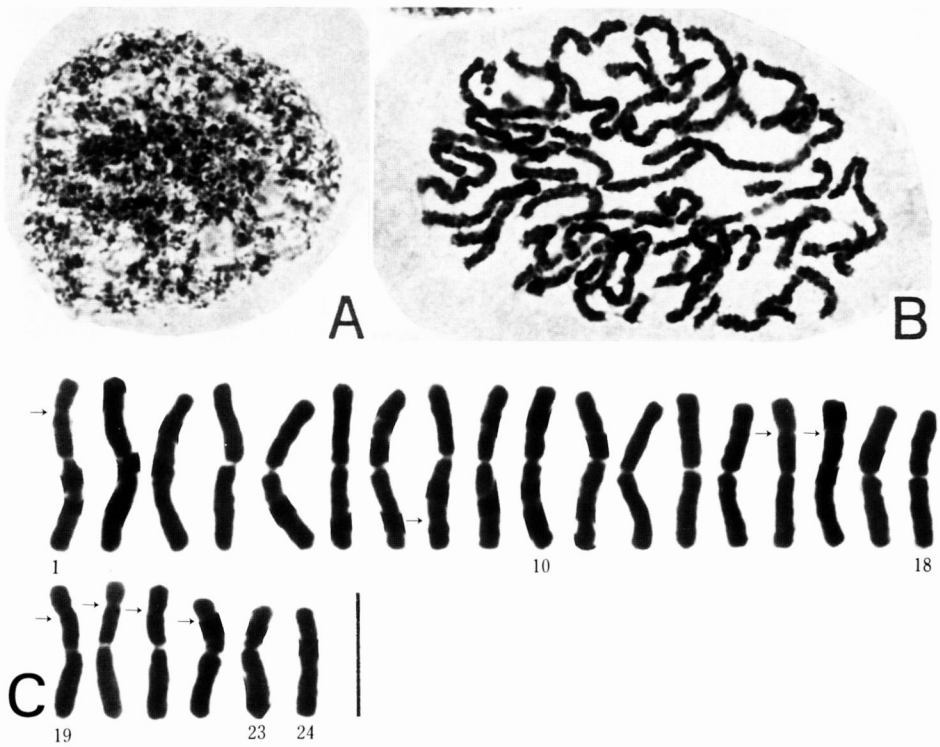

Fig. 52. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus canariensis* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

and Saylor (1983).

The chromosomes at interphase (Fig. 52A) and mitotic prophase (Fig. 52B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. A degradation in size from the longest chromosome of 14.3 μm to the shortest chromosome of 8.7 μm was observed in the mitotic metaphase karyotype which was quite homogeneous. Most of the chromosomes showed their centromeres located at median regions but a pair of the shortest chromosomes showed their centromeres at median-submedian regions (Fig. 52C). The chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms of five pairs (the 1st, 4th, 8th, 10th, 11th) of metacentric chromosomes. The karyomorphological feature of metaphase chromosomes is essentially similar to that reported by Mehra & Khoshoo (1956), Pederick (1970) and Saylor (1983) except for number and location of secondary constriction.

55. *Pinus roxburghii* Sarg., 2n=24, Fig. 53

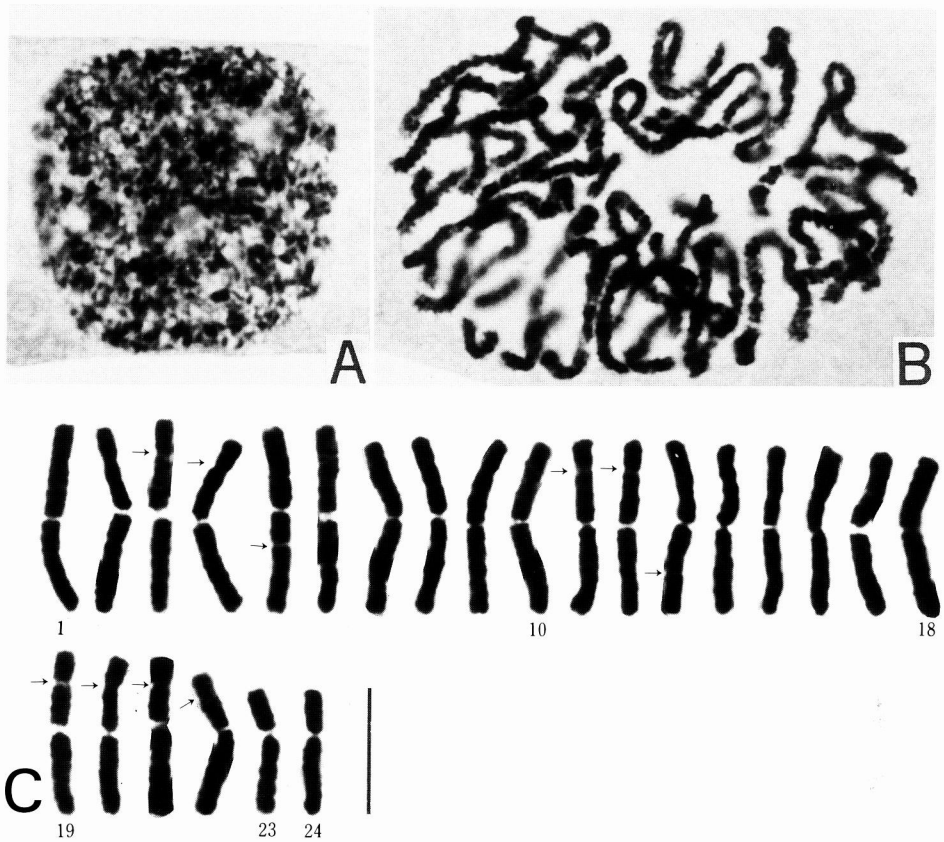

Fig. 53. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus roxburghii* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

Two years-old seedlings from the seeds collected in India (Table 1) were used for cytological observation. The chromosome number of 2n=24 was counted in all plants examined. This result confirms that the previous reports by Mehra & Khoshoo (1956), Chetty *et al.* (1970), Upadhaya & Kedharnath (1970) and Saylor (1972).

The chromosomes at interphase (Fig. 53A) and mitotic prophase (Fig. 53B) were similar karyomorphology to those in *P. strobus*. Thus, they are categorized to be the complex chromocenter type and the continuous type, respectively. At mitotic metaphase the chromosomes in each complement varied gradually in length from 15.4-9.9 μm and thus formed a very homogeneous complement. The majority of the chromosomes had their centromeres located at median regions while the pair of the shortest chromosomes had its centromere at median-submedian region (Fig. 53C). Thus, the chromosomes formed higly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms in six pairs (the 2nd, 3rd, 6th, 7th, 10th, 11th) of metacentric chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Mehra & Khoshoo (1956), Chetty *et al.* (1970), Upadhaya & Kedharnath (1970) and Saylor (1972) with differences in number and location of secondary constriction.

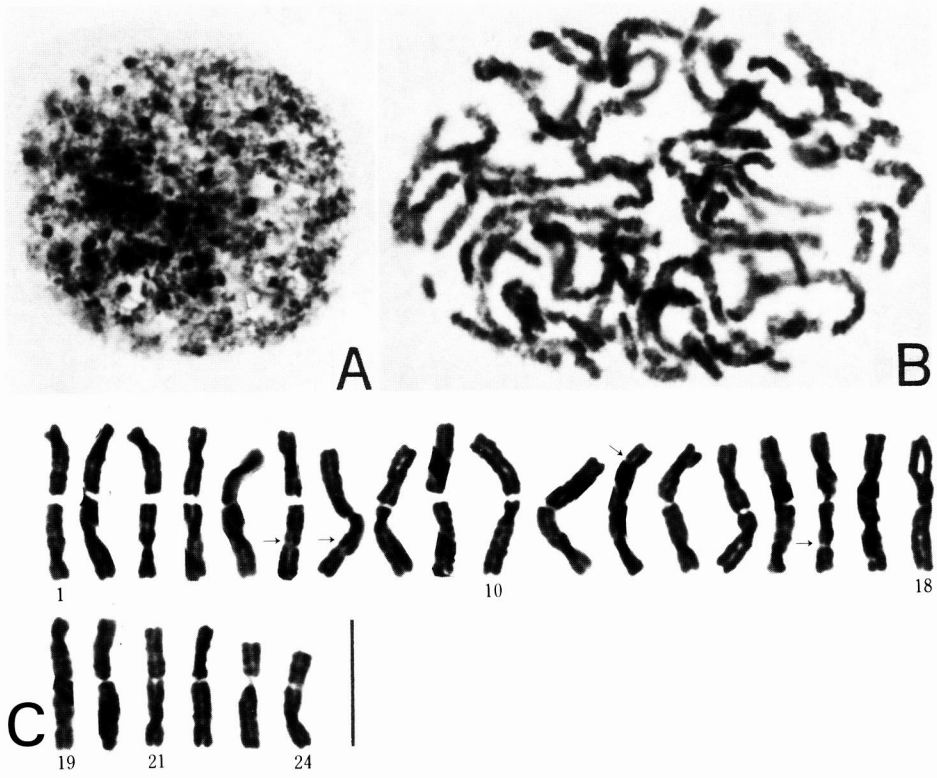

Fig. 54. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus pinea* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

56. *Pinus pinea* L., 2n=24, Fig. 54

Three seedlings (Table 1) were obtained for karyomorphological observation. The chromosome number for this species was counted to be 2n=24, which confirmed that reported by Saylor (1972).

The chromosomes at interphase (Fig. 54A) and mitotic prophase (Fig. 54B) were observed similar to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. At mitotic metaphase the chromosomes in each complement varied gradually in length from 11.8–7.9 μm and formed highly homogeneous complement. Most of the chromosomes were metacentric while the pair of the shortest chromosomes was submetacentric (Fig. 54C). Thus, they formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms on three pairs (the 4th, 6th, 8th) of metacentric chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Saylor (1972) except for number and locality of secondary constriction.

57. *Pinus resinosa* Ait., 2n=24, Table 12 and Fig. 55

The seeds collected in Mac Diarmid, Ontario, Canada were germinated and their root

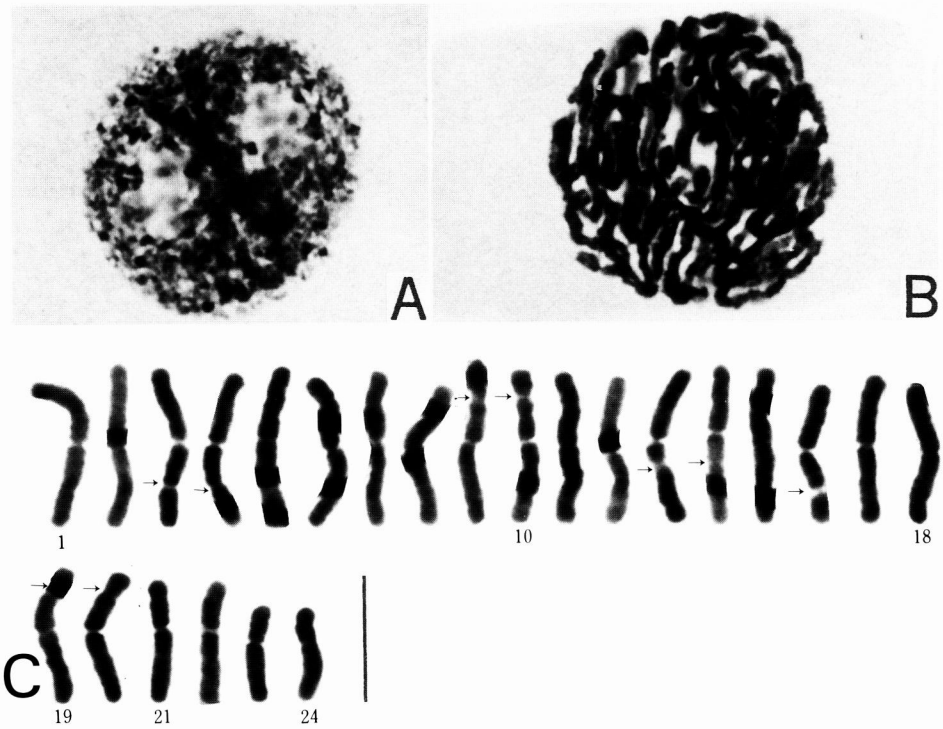

Fig. 55. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus resinosa* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

tips were used for cytological observation. The chromosome number was counted to be 2n=24 in all plants studied, which confirmed the previous reports by Sax & Sax (1933), Saylor (1961, 1964) and Price *et al.* (1973).

The chromosomes at interphase (Fig. 55A) and mitotic prophase (Fig. 55B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. Up to 14 nucleoli were observed in each nucleus. At mitotic metaphase the chromosomes of the complement varied gradually in length from 11.8–7.9 μm and formed highly homogeneous complement (Table 12). Two pairs of shorter chromosomes decreased hastily in length. Centromeres were located at median positions of most of the chromosomes and, however, were located at median–submedian regions in two pairs of the shorter chromosomes (Fig. 55C). Thus, the chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms of five pairs (the 2nd, 5th, 7th, 8th, 10th) of metacentric chromosomes. The karyomorphological feature at metaphase is essentially similar to that reported by Sax & Sax (1933) and Saylor (1961, 1964) with exception of number and location of secondary constriction.

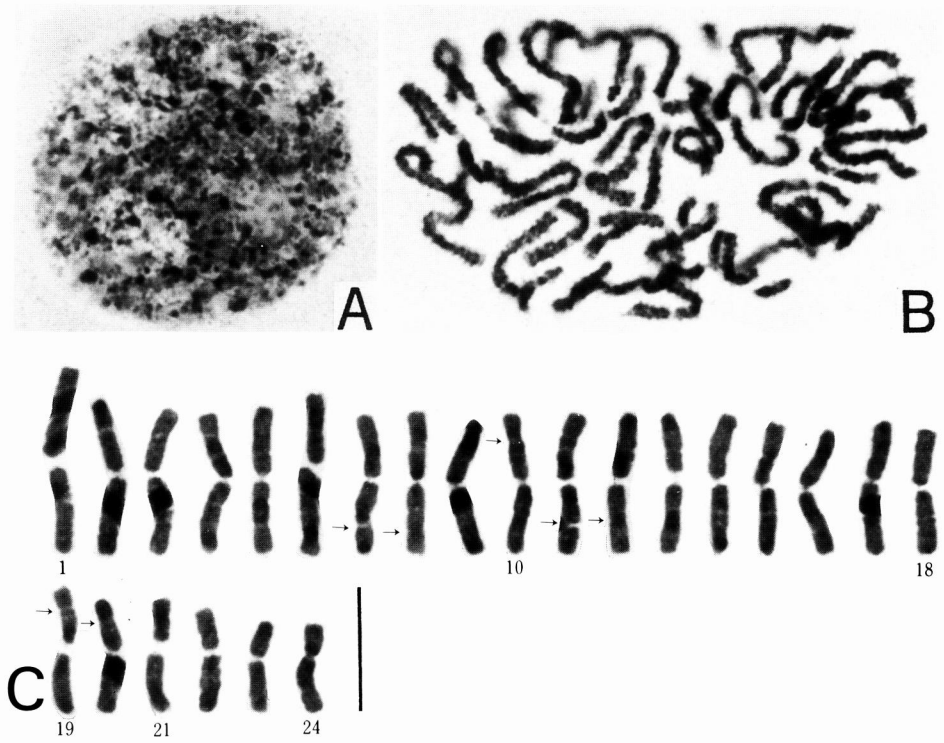

Fig. 56. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus nigra* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

58. *Pinus nigra* Arnold, 2n=24, Fig. 56

The seedlings from seeds and five young trees (Table 1) were used for karyomorphological observation. The chromosomes number for this species was counted to be 2n=24. This chromosome count confirms the previous documents by Sax & Sax (1933), Mehra & Khoshoo (1956), Saylor (1964), Pederick (1970), Mihailailescu & Dalu (1971, 1972), Kormuták (1975), Borzan (1977, 1981), Borzan & Papeš (1978), Baranec (1979), MacPherson & Filion (1981) and Kaya *et al.* (1985).

The chromosomes at interphase (Fig. 56A) and mitotic prophase (Fig. 56B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. A degradation in chromosome size from the longest one of 12.4 μm to the shortest one of 6.9 μm was observed in each mitotic metaphase karyotype which formed highly homogeneous complement. Two pairs of the shorter chromosomes decreased hastily in length as observed in *P. resinosa*. The majority of the chromosomes showed the centromere located at median position, while the 11th pair of shorter chromosomes showed the centromere located at median-submedian position and the 12th pair of shorter chromosomes the centromere located at submedian position (Fig. 56C). Thus, the chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms on four pairs of metacentric chromosomes (the 4th, 5th, 6th, 10th pairs). The karyotype at mitotic metaphase is essentially similar to that reported by Sax & Sax (1933), Mehra & Khoshoo (1956), Saylor (1964), Pederick (1970), Mihailailescu & Dalu (1971, 1972), Kormuták (1975), Borzan (1977, 1981), Borzan & Papeš (1978), Baranec (1979), MacPherson & Filion (1981) and Kaya *et al.* (1985) except for number and location of secondary constriction.

59. *Pinus mugo* Turra, 2n=24, Fig. 57

Three young trees (Table 1) were used for karyomorphological observation. The chromosome number was counted to be 2n=24 in the three plants. This chromosome count confirms the previous documents by Sax & Sax (1933), Sarker (1963), Kormuták (1975) and Baranec (1979).

The chromosomes at interphase (Fig. 57A) and mitotic prophase (Fig. 57B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase plate the chromosomes varied gradually in length from 11.8–7.5 μm and formed highly homogeneous complement. Two pairs of shorter chromosomes decreased hastily in length. The chromosomes had the centromeres at median regions excepting for the pairs of the shorter chromosomes had the centromeres at median-submedian regions (Fig. 57C). Thus, the chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of arms on six pairs of metacentric chromosomes (the 1st, 2nd, 3rd, 5th, 7th, 10th). Small constrictions appeared sometimes at

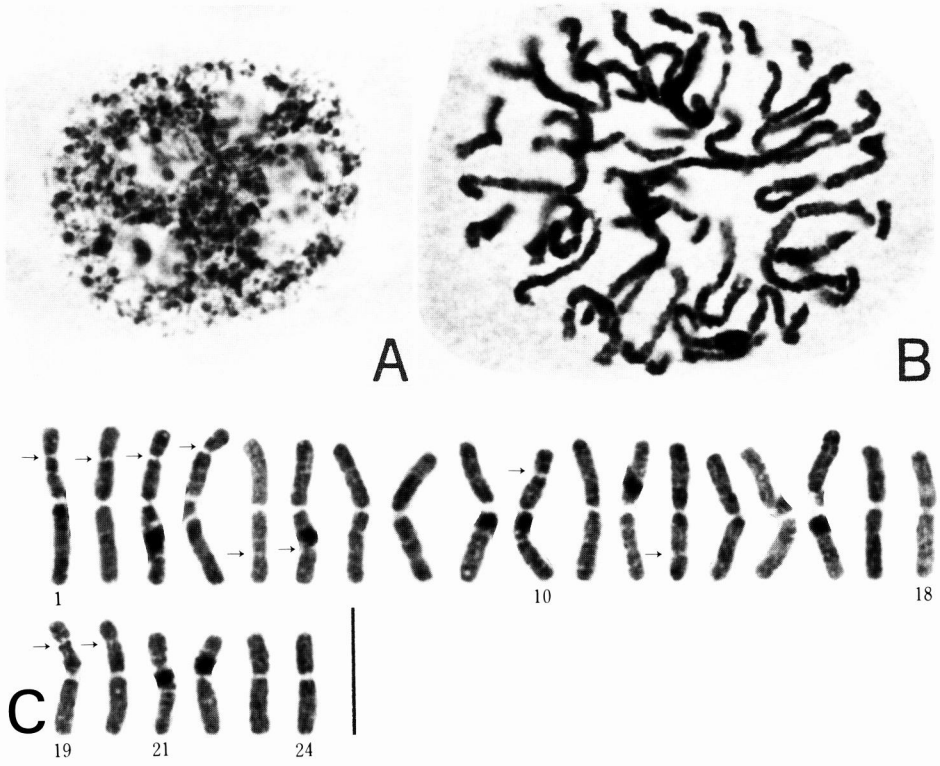

Fig. 57. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus mugo* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

interstitial regions of some chromosomes. The karyomorphological feature of the chromosomes at metaphase is essentially similar to that reported by Sax & Sax (1933), Sarker (1963), Kormuták (1975) and Baranec (1979) except for number and location of secondary constriction.

60. *Pinus pinaster* Ait., 2n=24, Fig. 58.

Four young trees (Table 1) were used for karyomorphological observation. The chromosome number of 2n=24 was documented here and confirmed the previous reports by Mehra & Khoshoo (1956), Shibata *et al.* (1956), Saylor (1964), Kuroki (1969), Pederick (1970), Moromizato (1975).

The chromosomes at interphase (Fig. 58A) and mitotic prophase (Fig. 58B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase plate the chromosomes varied gradually in length from 12.6–7.7 μm and formed highly homogeneous complement. Two pairs of the shorter chromosomes decreased hastily in length. The chromosomes contained the centromeres at median regions excepting for the pairs of shorter chromosomes contained their centromeres at median–submedian or submedian

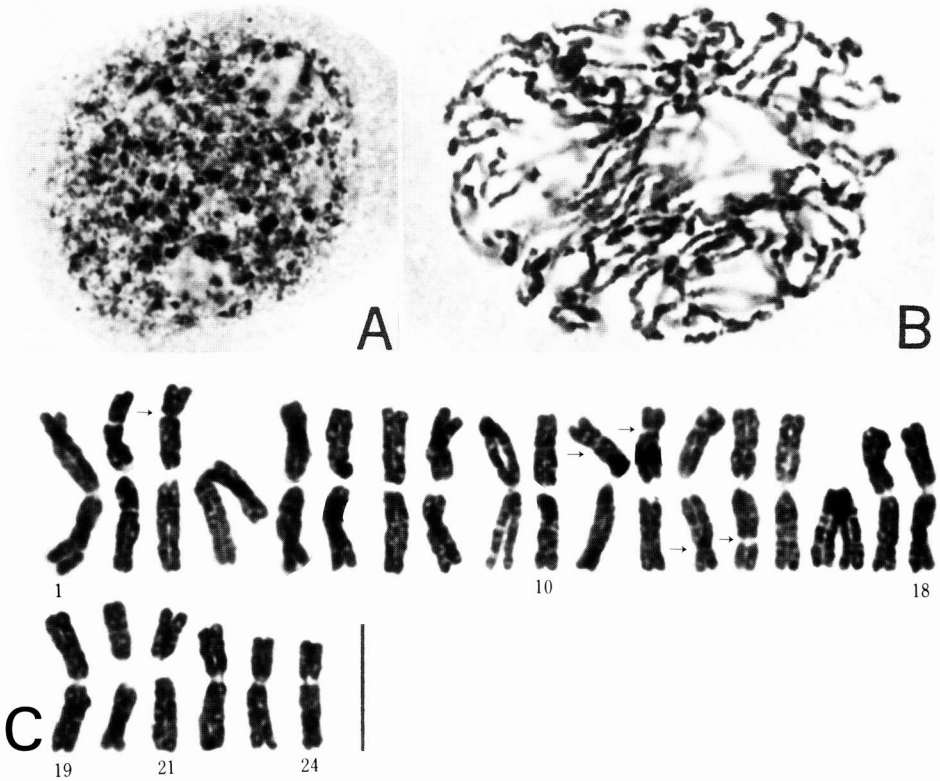

Fig. 58. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus pinaster* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

regions (Fig. 58C). Thus, the chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms of three pairs (the 2nd, 6th, 7th) of metacentric chromosomes. Several other secondary constrictions also appeared sometimes in some chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Mehra & Khoshoo (1956), Saylor (1964), Kuroki (1969), Pederick (1970) and Moromizato (1975) except for number and location of secondary constriction.

61. *Pinus stankewiczii* Ait., 2n=24, Fig. 59.

Three two-year-old plants (Table 1) were used for cytological observation. The chromosome number was counted to be 2n=24 here for the first time.

The chromosomes at interphase (Fig. 59A) and mitotic prophase (Fig. 59B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase plate the chromosomes varied gradually in length from 13.8–9.0 μm and formed highly homogeneous complement. Two pairs of shorter chromosomes decreased hastily in

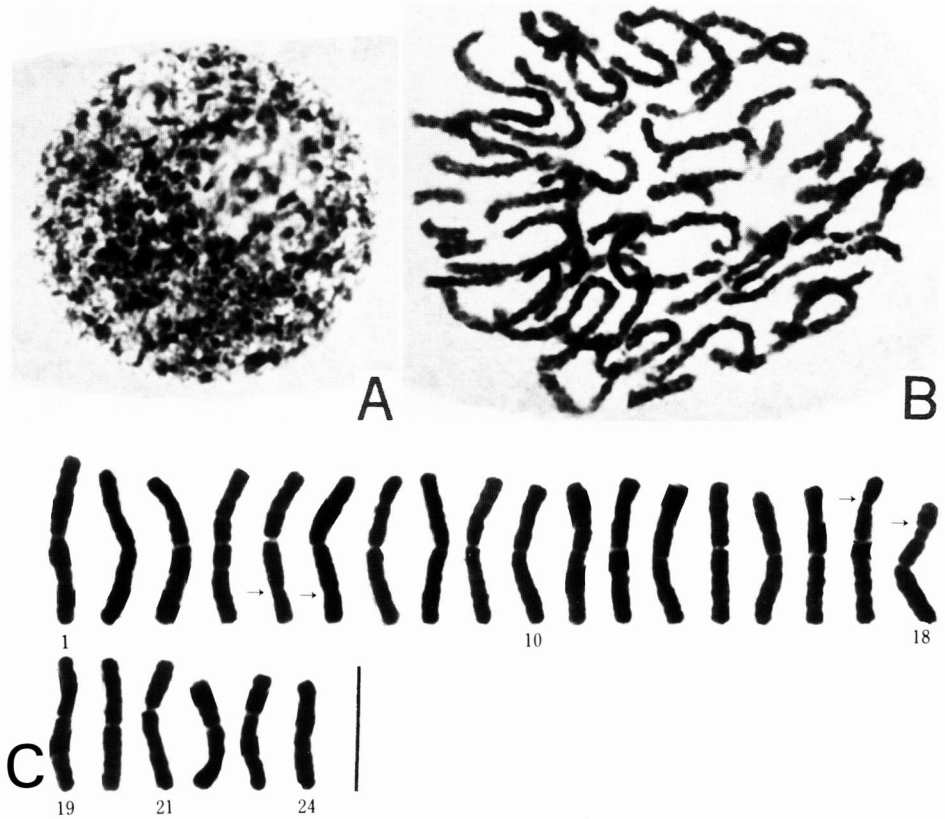

Fig. 59. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus stankewiczii* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

length. The chromosomes had the centromeres at median regions excepting for the pairs of the shorter chromosomes had their centromeres at submedian regions (Fig. 59C). The chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of their arms in three pairs of metacentric chromosomes (th 3rd, 4th, 6th).

62. *Pinus brutia* Ten., 2n=24, Fig. 60

The germinated seeds obtained from two sources in Italy (Table 1) were used for cytological observation. The chromosome number was counted to be 2n=24 in all plants, which confirmed the previous report by Saylor (1964).

The chromosomes at interphase (Fig. 60A) and mitotic prophase (Fig. 60B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. The mitotic metaphase plate showed the chromosome degradation in size from the longest chromosome of 16.2 μm to the shortest chromosome of 11.0 μm, and thus indicated highly homogeneous chromosome

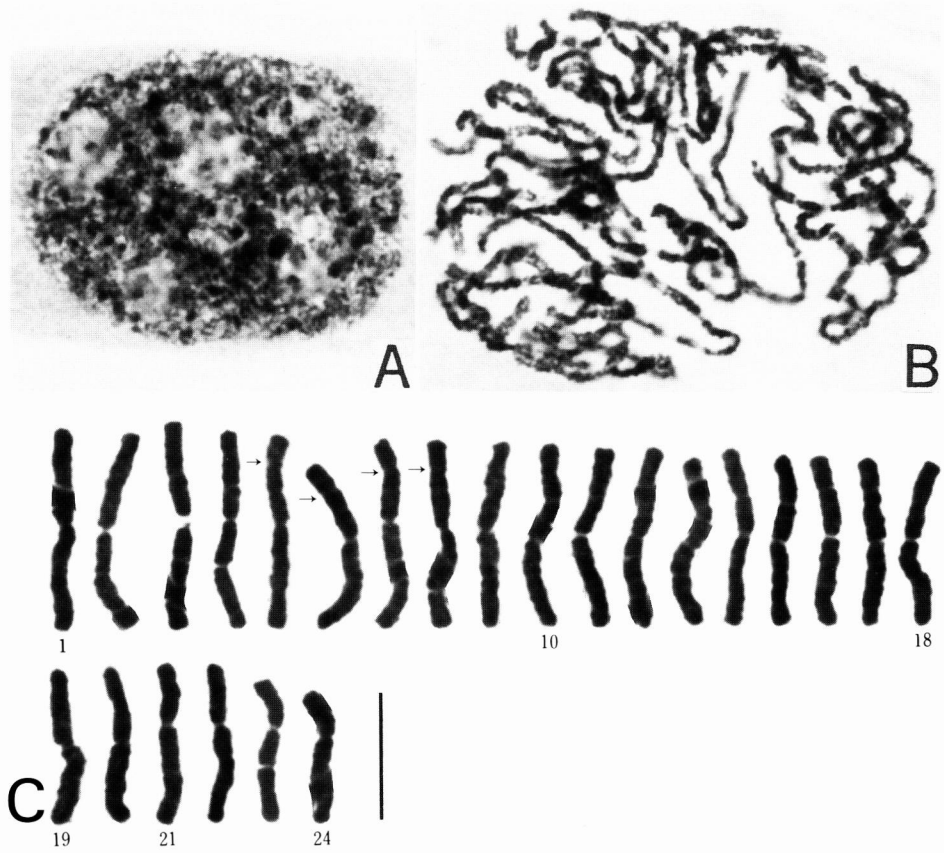

Fig. 60. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus brutia* (2n = 24). Bar indicates 10 μm and arrows indicate secondary constrictions.

complement. Two pairs of shorter chromosome decreased hastily in length. The chromosomes had the centromeres located at median regions excepting for the 11th pair of chromosomes had its centromere located at median–submedian region and the 12th pair had the centromere located at submedian region (Fig. 60C). The chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms of two pairs (the 3rd, 4th) of metacentric chromosomes. The other secondary constructions and small constrictions were also observed occasionally in several chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Saylor (1964) with exception of number and location of the secondary constriction.

63. *Pinus sylvestris* L., 2n=24, Fig. 61

Three two years-old plants and some seedlings germinated from the seeds (Table 1) were used for cytological observation. The chromosome number was counted to be 2n=24

in all plants. This chromosome count confirms the previous documents by Sax & Sax (1933), Aass (1957), Vidakovic (1958), Natarajan *et al.* (1961), Saylor (1964), Fahmy (1966), Mihailailescu & Dalu (1972), Kormuták (1975), Baranec (1979), Borzan (1981) and Chang & Li (1982).

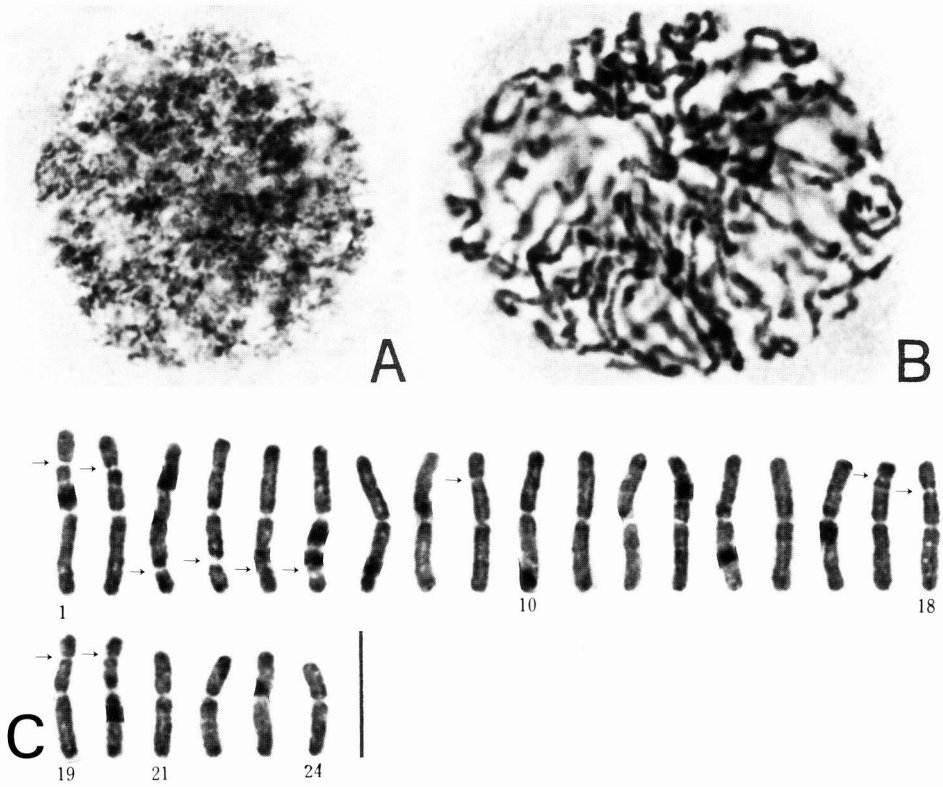

Fig. 61. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus sylvestris* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 61A) and mitotic prophase (Fig. 61B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase plate the chromosomes varied gradually in length from 12.6–7.7 μm and formed highly homogeneous complement. Two pairs of shorter chromosomes decreased hastily in length. Centromeres were located at median regions of most of the chromosomes or at median–submedian or submedian regions in the pairs of shorter chromosomes (Fig. 61C). Thus, the chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms of six pairs of metacentric chromosomes (the 1st, 2nd, 3rd, 5th, 9th, 10th). The karyotype at mitotic metaphase is essentially similar to that reported by Sax & Sax (1933), Aass (1957), Vidakovic (1958), Natarajan *et al.* (1961), Saylor (1964), Fahmy (1966), Mihailailescu & Dalu (1972),

Kormuták (1975), Baranec (1979), Borzan (1981) and Chang & Li (1982) with differences in number and location of secondary constriction.

64. *Pinus densiflora* Sieb. & Zucc., 2n=24, Fig. 62 (Japanese name : Aka-matsu)

The seeds were collected from 14 localities in Japan (Table 1) and were germinated. Their root tips were used for cytological observation. The chromosome number was 2n=24, which confirmed the previous documents by Hirayoshi *et al.* (1943), Zinnai (1952), Sarker (1963), Saylor (1962), Shidei & Moromizato (1965), Kuroki (1969), Funabiki *et al.* (1970), Moromizato *et al.* (1972), Price *et al.* (1973) and Tanaka & Hizume (1980), but did not support the previous tetraploid count (Zinnai 1952).

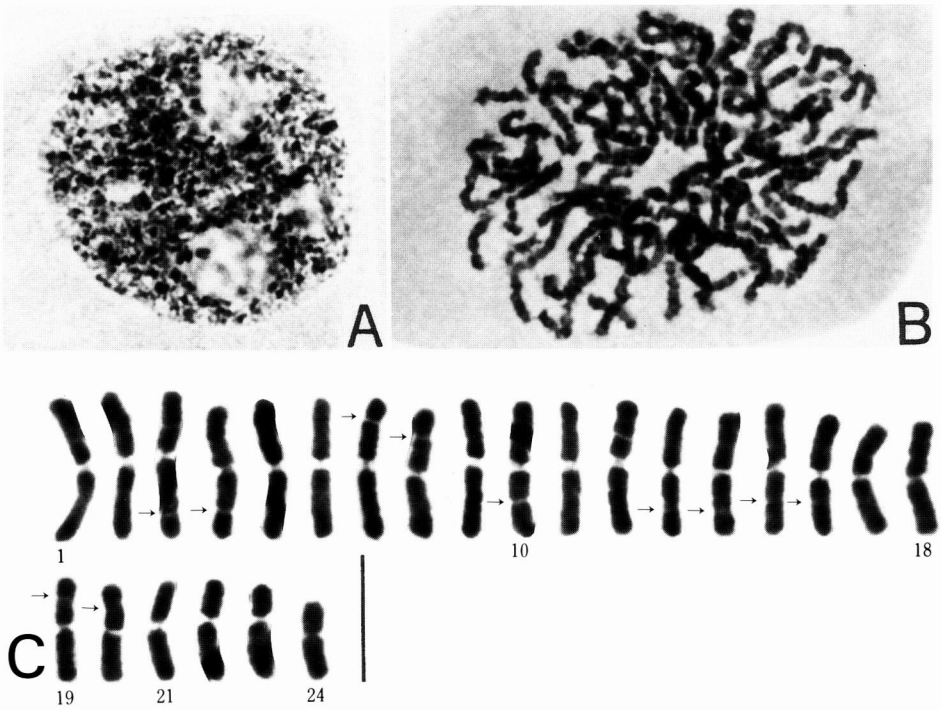

Fig. 62. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus densiflora* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 62A) and mitotic prophase (Fig. 62B) were similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. The chromosomes of the mitotic metaphase complement varied gradually in length from 12.0–6.4 μm and formed highly homogeneous complement. Two pairs of shorter chromosome decreased hastily in length. The chromosomes had the centromeres at median regions excepting for the pairs of shorter chromosomes had the centromeres at median–submedian or submedian regions (Fig. 62C).

Thus, the chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms in six pairs (the 2nd,4th, 5th, 7th, 8th, 10th) of metacentric chromosomes. Small constriction was located constantly at near region of the secondary constriction of the 10th pair and the other were also observed sometimes elsewhere. The karyotype at mitotic metaphase is essentially similar to that reported by Sarker (1963), Saylor (1964), Shidei & Moromizato (1965), Kuroki (1969), Funabiki *et al.* (1970), Moromizato *et al.* (1972) and Tanaka & Hizume (1980) with differences in number and location of secondary constriction.

65. *Pinus thunbergii* Parl., 2n=24, Fig. 63 (Japanese name : Kuro-matsu)

The seeds collected from three localities in Japan (Table 1) were germinated. Their root tips were used for cytological observation. The chromosome number was counted to be 2n=24 in all plants, which confirmed the previous documents by Hirayoshi *et al.* (1943), Kanezawa (1949), Shibata *et al.* (1955, 1956), Saylor (1964), Shidei & Moromizato (1965), Kuroki (1969), Funabiki & Seido (1968), Funabiki *et al.* (1970), Moromizato *et al.* (1972) and Moromizato (1975).

The chromosomes at interphase (Fig. 63A) and mitotic prophase (Fig. 63B) were very

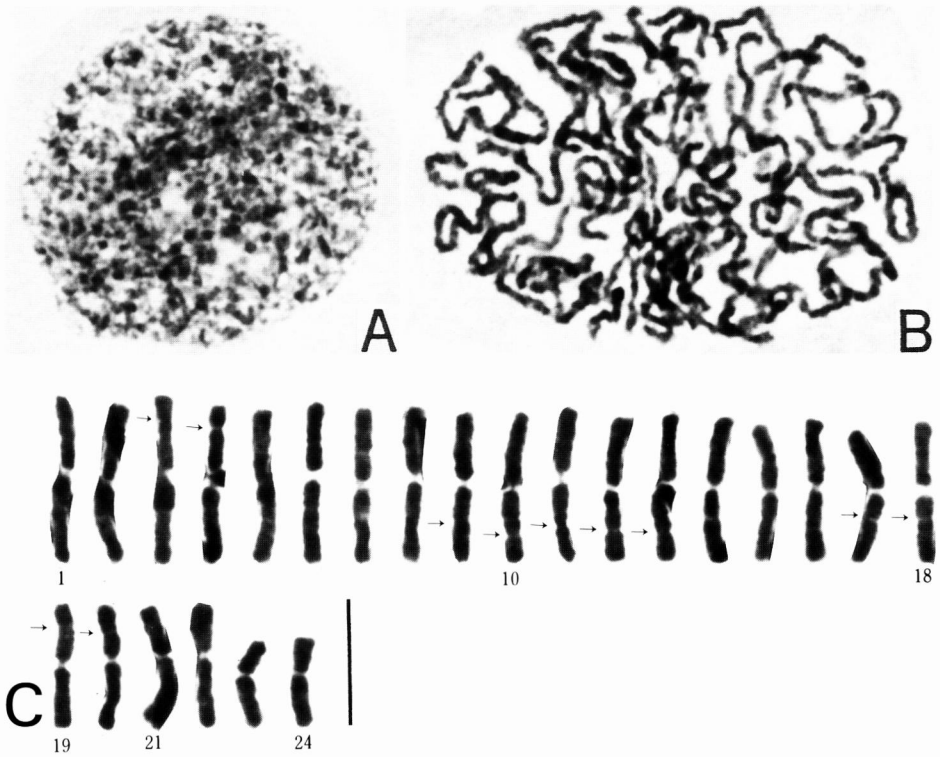

Fig. 63. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus thunbergii* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

similar in karyomorphology to those in *P. densiflora*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase plate the chromosomes varied gradually in length from 13.5–6.8 μm and formed highly homogeneous complement. Two pairs of shorter chromosomes decreased hastily in length. Centromeres were located at median regions of the chromosomes except for one at median–submedian regions in the pairs of shorter chromosomes (Fig. 63C). Thus, the chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms of one of the arms of five pairs (the 2nd, 5th, 6th, 9th, 10th) of chromosomes. As observed in *P. densiflora*, small constriction was located constantly near the region of the secondary constriction of the 10th pair of chromosomes and another constrictions were also observed sometimes. The karyotype at mitotic metaphase is essentially similar to that reported by Saylor (1964), Shidei & Moromizato (1965), Kuroki (1969), Funabiki & Seido (1968), Funabiki *et al.* (1970), Moromizato *et al.* (1972) and Moromizato (1975) but is different in number and location of secondary construction.

66. *Pinus luchuensis* Mayr, 2n=24, Fig. 64 (Japanese name : Ryukyu-matsu)

The seeds obtained from Okinawa Pref., Japan were germinated and their root tips

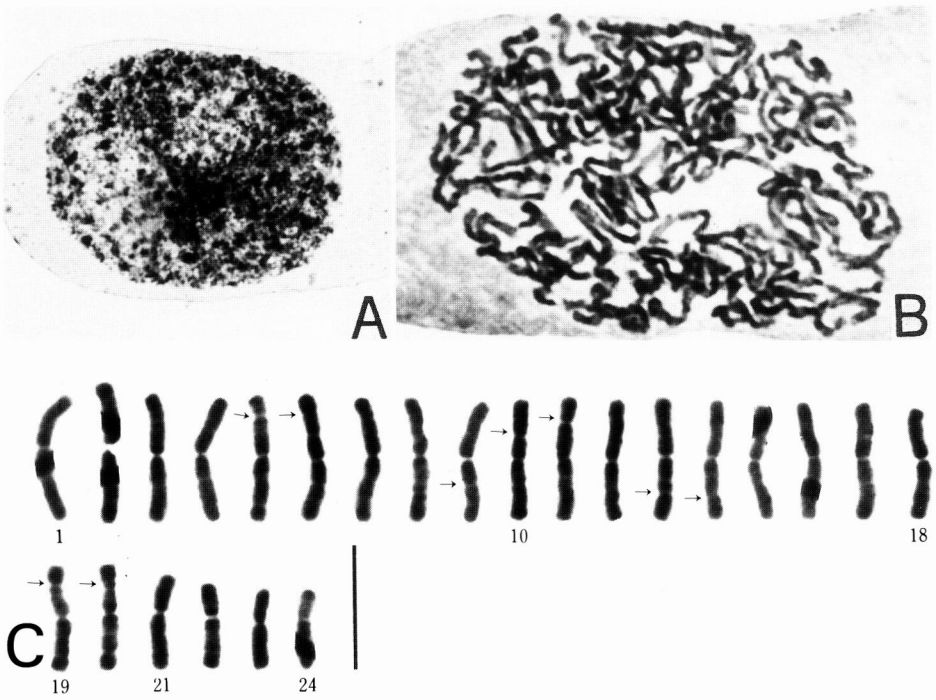

Fig. 64. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus luchuensis* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

were used for cytological observation. The chromosome number was counted to be 2n=24 in all plants, which confirmed the previous reports by Shibata *et al.* (1956), Saylor (1964), Kuroki (1969) and Shidei & Moromizato (1971).

The chromosomes at interphase (Fig. 64A) and mitotic prophase (Fig. 64B) were very similar in karyomorphology to those in *P. densiflora*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase plate the chromosomes varied gradually in length from 10.7–6.3 μm and formed highly homogeneous complement. Two pairs of shorter chromosomes decreased hastily in length. Centromeres were located at median regions of most of the chromosomes or at median–submedian regions of the pairs of shorter chromosomes (Fig. 64C). Thus, the chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms of five pairs of metacentric chromosomes (the 3rd, 5th, 6th, 7th, 10th pairs). As observed in *P. densiflora*, small constriction was found constantly near region of the secondary constriction on the 10th pair of chromosomes and another constrictions were also observed sometimes. The karyotype at mitotic metaphase is essentially similar to that reported by Saylor (1964), Kuroki (1969) and Shidei & Moromizato (1971) except for number and location of secondary constriction.

67. *Pinus yunnanensis* Franch., 2n=24, Fig. 65

The seeds collected in the People's Republic of China (Table 1) and were germinated and their root tips were used for cytological observation. The chromosome number was counted to be 2n=24 in all plants, which confirmed the previous report by Saylor (1964).

The chromosomes at interphase (Fig. 65A) and mitotic prophase (Fig. 65B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase plate the chromosomes varied gradually in length from 16.0–9.2 μm and formed highly homogeneous complement. Two pairs of shorter chromosomes decreased hastily in length. Most of the chromosomes were metacentric while two pairs of shorter chromosomes were meta–submetacentric (Fig. 65C). The chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms of five pairs (the 4th, 7th, 8th, 9th, 10th) of chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Saylor (1964) except for number and location of secondary constriction.

68. *Pinus khasya* Royle, 2n=24, Fig. 66

The seeds obtained from Tailand (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number was counted to be 2n=24 in all plants, which confirmed the previous reports by Mehra & Khoshoo (1956) and Saylor (1964).

The chromosomes at interphase (Fig. 66A) and mitotic prophase (Fig. 66B) were very

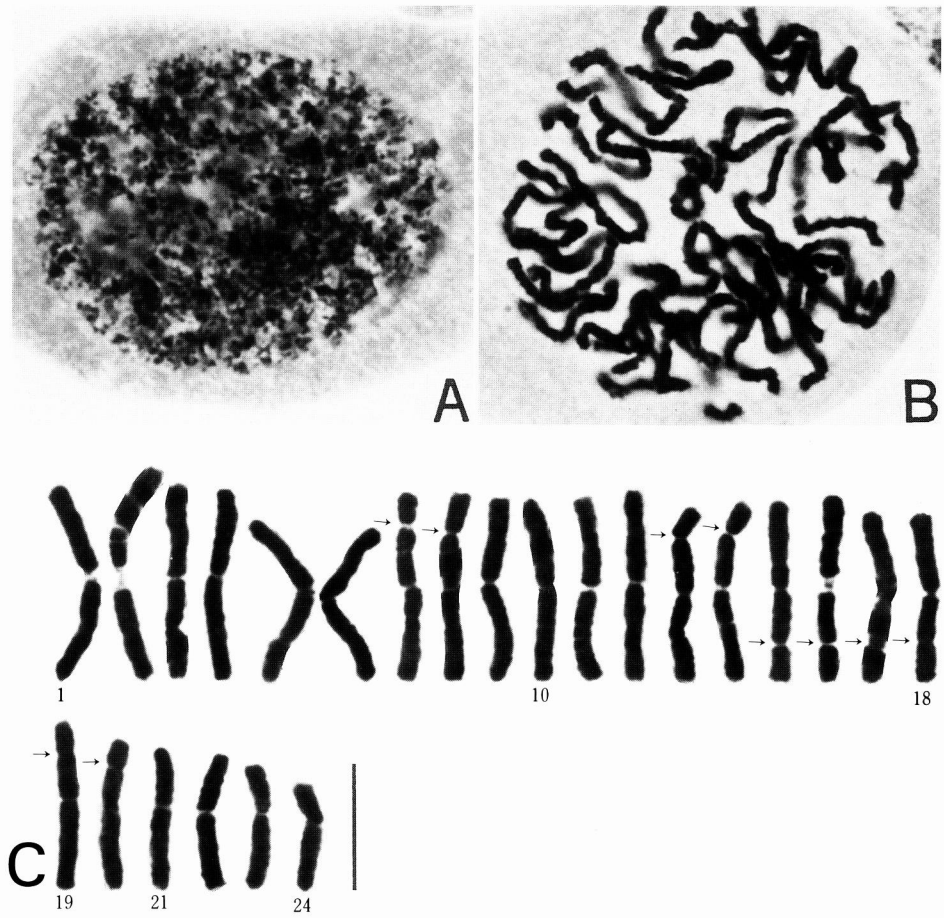

Fig. 65. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus yunnanensis* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. The chromosomes in each mitotic metaphase complement varied gradually in length from 15.8–9.5 μm and formed highly homogeneous complement. Two pairs of shorter chromosomes decreased hastily in length. Centromeres were found at median regions of most of the chromosomes and at median–submedian regions of two pairs of shorter chromosomes (Fig. 66C). The chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of their arms on five pairs (the 1st, 3rd, 5th, 8th, 10th) of chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Mehra & Khoshoo (1956) and Saylor (1964) with exception of number and location of secondary constriction.

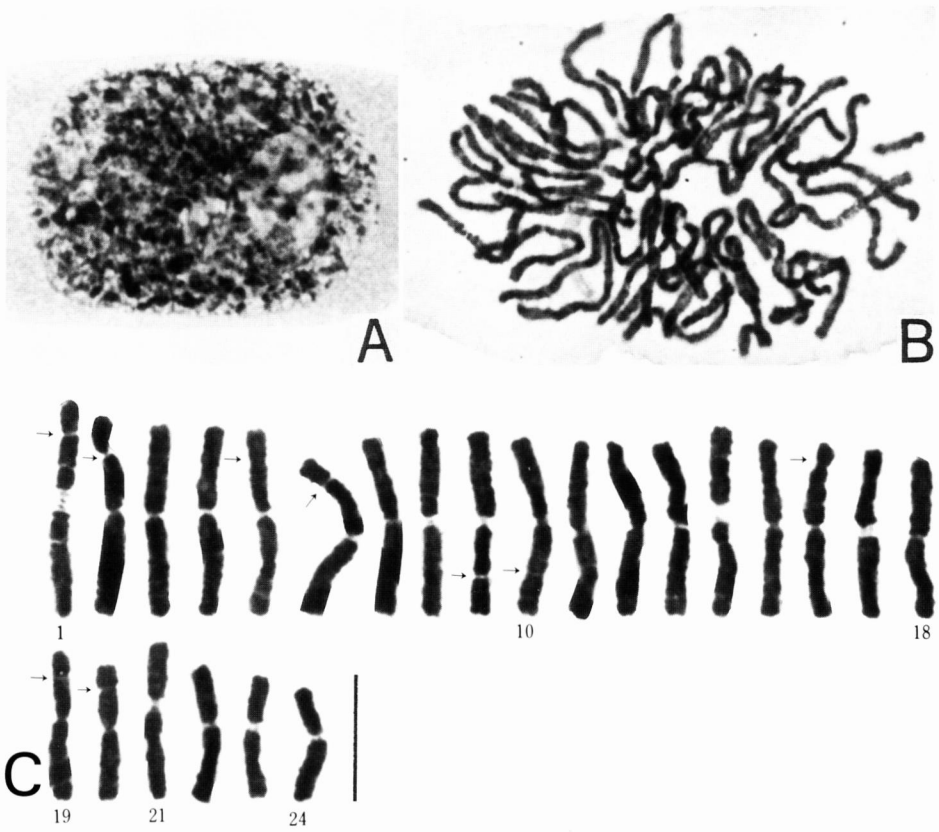

Fig. 66. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus khasya* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

69. *Pinus taeda* L., 2n=24, Fig. 67

The germinated seeds obtained from three origins and three young plants (Table 1) were used for karyomorphological observation. The chromosome number was counted to be 2n=24 in all plants studied. This result of the chromosome count confirms the previous reports by Kim (1952), Shibata *et al.* (1956), Saylor (1961) and Moromizato (1975).

The chromosomes at interphase (Fig. 67A) and mitotic prophase (Fig. 67B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase plate the chromosomes varied gradually in length from 15.6–9.5 μm and formed highly homogeneous complement. The pair of the shortest chromosomes decreased hastily in length. Centromeres were located at median regions of most of the chromosomes and at median –submedian region of the pair of the shortest chromosomes (Fig. 67C). Thus, the chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of their arms on five pairs (the 2nd, 3th, 7th, 9th, 10th) of chromosomes. The karyomorphological feature at metaphase is essentially

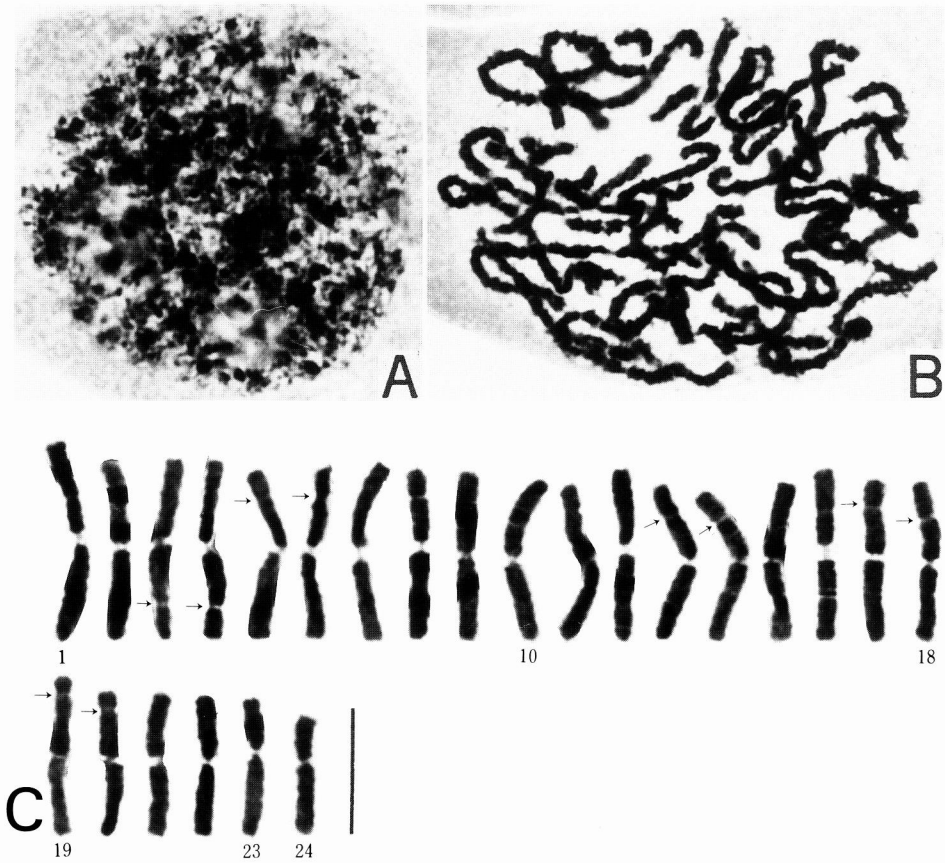

Fig. 67. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus taeda* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

similar to that reported by Kim (1952), Saylor (1961) and Moromizato (1975) except for secondary constriction.

70. *Pinus rigida* Mill., 2n=24, Fig. 68

The seeds obtained from two sources (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number was counted to be 2n=24 in all plants, which confirmed the previous documents by Kim (1952), Yim (1963), Saylor (1972) and Dhillon (1973).

The chromosomes at interphase (Fig. 68A) and mitotic prophase (Fig. 68B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. The mitotic metaphase chromosomes of the complement varied gradually in length from 14.1–8.3 μm and formed highly homogeneous complement. The pair of the shortest chromosomes decreased hastily in length. Most of the chromosomes were metacentric and one pair of the shortest chromo-

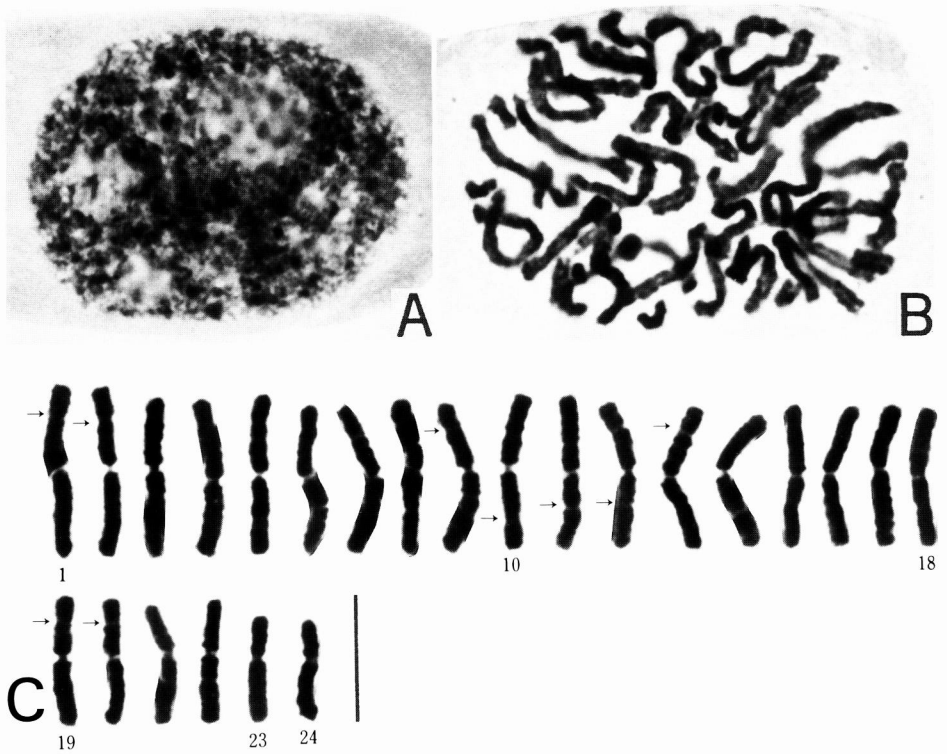

Fig. 68. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus rigida* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

somes was meta-submetacentric (Fig. 68C). The chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms of five pairs of metacentric chromosomes (the 1st, 5th, 6th, 7th, 10th pairs). The karyotype at mitotic metaphase is essentially similar to that reported by Kim (1952), Yim (1963), Saylor (1972) and Dhillon (1973) with exception of number and location of secondary constriction.

71. *Pinus serotina* Michx., 2n=24, Fig. 69

The seeds collected at Charleston, West Virginia, U.S.A. were germinated and their root tips were used for cytological observation. The chromosome number was counted to be 2n=24 in all plants, which confirmed the previous document by Saylor (1972).

The chromosomes at interphase (Fig. 69A) and mitotic prophase (Fig. 69B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase plate the chromosomes varied gradually in length from 11.1–7.0 μm and formed highly homogeneous complement. The pair of the shortest chromosomes decreased hastily in length. Centromeres were located at median regions of most of the chromosomes and at

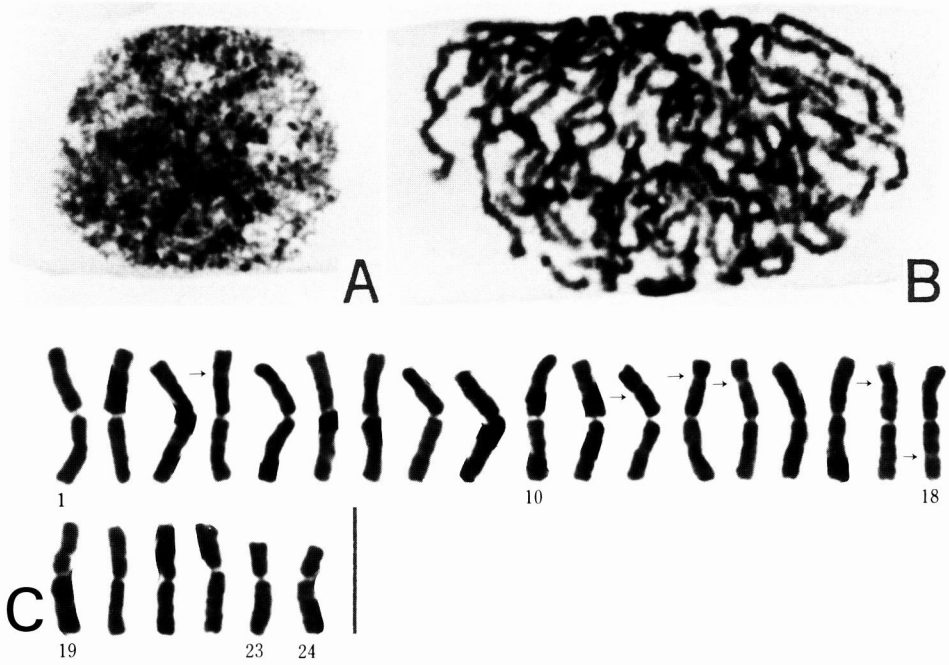

Fig. 69. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus serotina* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

median–submedian region in the pair of the shortest chromosomes (Fig. 69C). The chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of their arms on four pairs (the 2nd, 6th, 7th, 9th) of the metacentric chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Saylor (1972) with exception of number and location secondary constriction.

72. *Pinus pungens* Lamb., 2n=24, Fig. 70

The seeds collected at Rabun, Georgia, U.S.A. were germinated and their root tips were used for cytological observation. The chromosome number of 2n=24 was counted in all plants, and confirmed the previous report by Saylor (1970).

The chromosomes at interphase (Fig. 70A) and mitotic prophase (Fig. 70B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase plate the chromosomes varied gradually in length from 12.2–7.4 μm and formed highly homogeneous complement. The pair of the shortest chromosomes decreased hastily in length. The chromosomes showed the centromeres at median positions excepting for the pair of the shortest chromosomes showed the centromere at median–submedian position (Fig. 70C). Thus, the chromosomes formed highly symmetrical complement. Secondary constric-

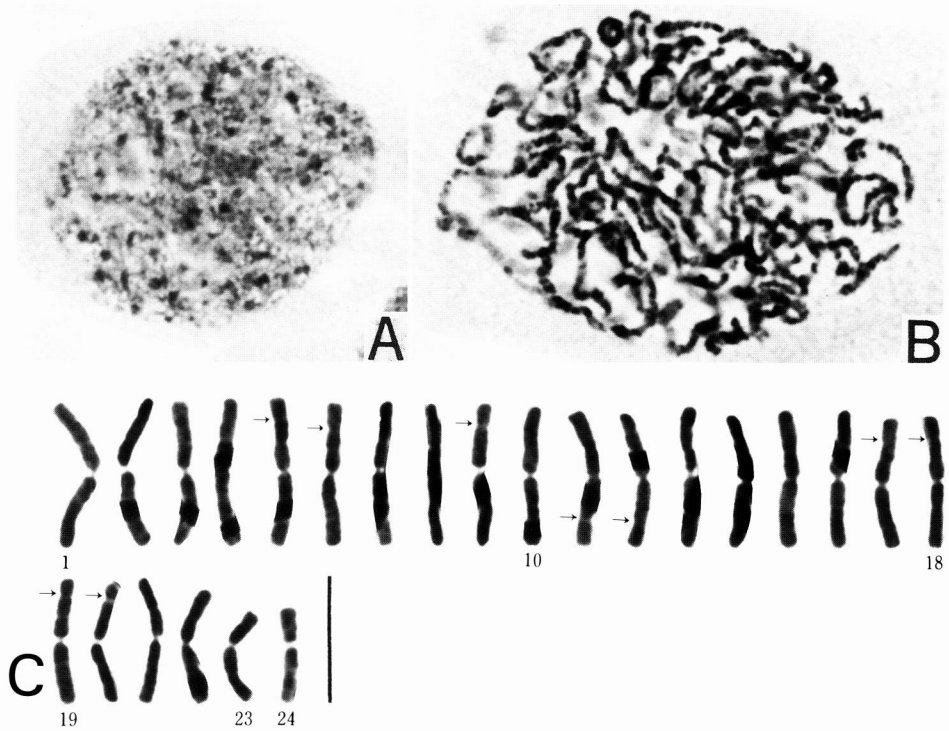

Fig. 70. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus pungens* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

tions were frequently observed at interstitial regions of one of their arms on five pairs (the 3rd, 5th, 6th, 9th, 10th) of chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Saylor (1972) except for number and location of secondary constriction.

73. *Pinus elliottii* Engelm., 2n=24, Fig. 71

The germinated seeds obtained from U.S.A. and three young plants (Table 1) were used for cytological observation. The chromosome number for this species was counted to be 2n=24, which confirmed the previous documents by Mergen & Novotmy (1957), Mergen (1958), Saylor (1972) and Moromizato (1975) except for the tetraploid document (Mergen 1958).

The chromosomes at interphase (Fig. 71A) and mitotic prophase (Fig. 71B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. A gradual decrease in size from the longest chromosomes of 11.3 μm to the shortest chromosomes of 7.0 μm was observed in the mitotic metaphase karyotype of the highly homogeneous complement. The pair of the shortest chromosomes decreased hastily in length. Most of the chromosomes had their centromeres at median regions and the pair of the shortest chromosomes had the cen-

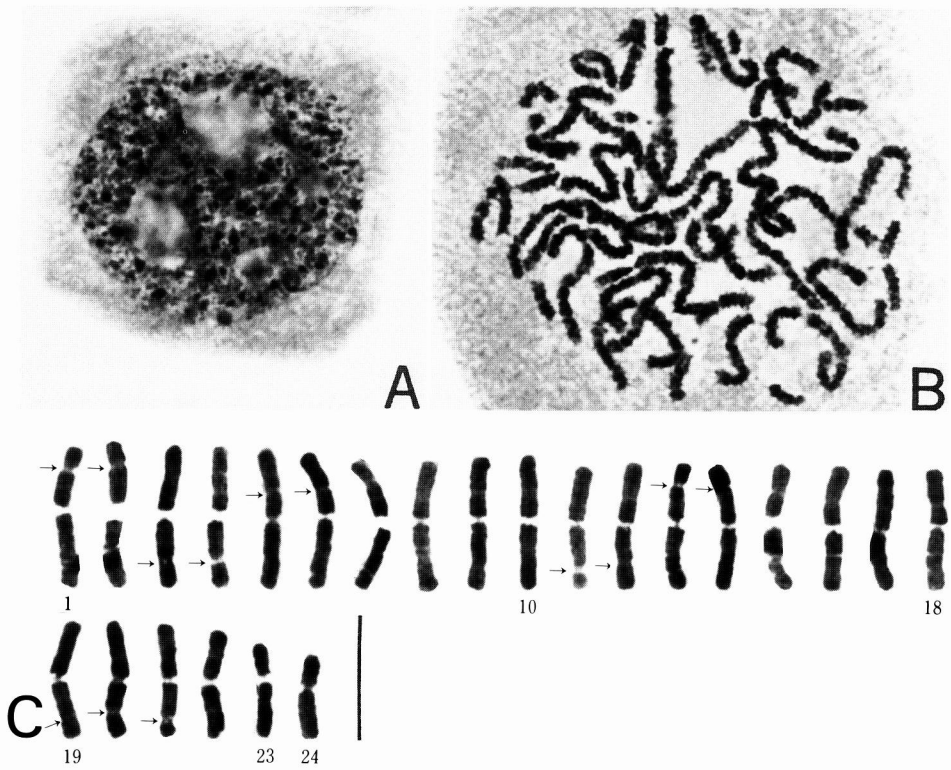

Fig. 71. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus elliottii* (2n = 24). Bar indicates 10 μm and arrows indicate secondary constrictions.

tromere at submedian region (Fig. 71C). Thus, chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of their arms on seven pairs (the 1st, 2nd, 3rd, 6th, 7th, 10th, 11th) of metacentric chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Saylor (1972) and Moromizato (1975) with exception of number and location of secondary constriction.

74. *Pinus caribaea* var. *hondurensis* Barr. & Golt, 2n=24, Fig. 72

The seeds obtained from Honduras (Table 1) were germinated and their root tips were used for cytological observation. All plants studies showed the chromosome number of 2n=24, which confirmed the previous reports by Mehra & Khoshoo (1956), Shibata *et al.* (1956), Kuroki (1969), Saylor (1972) and Salazar (1983).

The chromosomes at interphase (Fig. 72A) and mitotic prophase (Fig. 72B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. The chromosomes of the mitotic metaphase complement varied gradually in length from 12.1–8.2 μm and formed highly homogeneous complement. The pair of the shortest chromosomes decreased hastily in

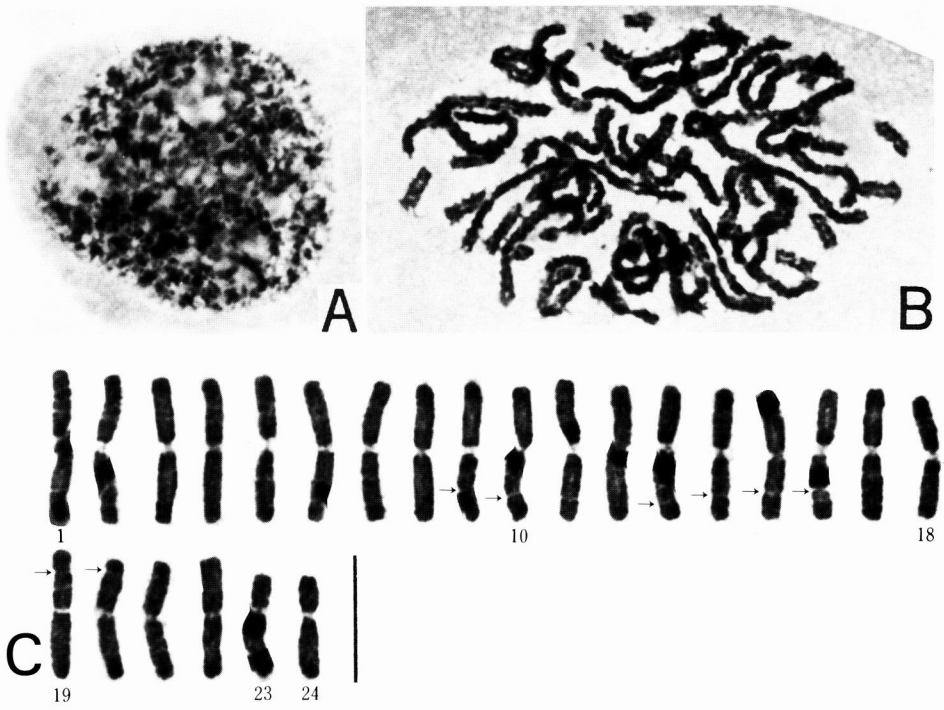

Fig. 72. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus caribaea* var. *hondurensis* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

length. Centromeres were located at median positions of most of the chromosomes and at median-submedian position in the pair of the shortest chromosomes (Fig. 72C). The chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of their arms on four pairs (the 5th, 7th, 8th, 10th) of metacentric chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Mehra & Khoshoo (1956), Kuroki (1969), Saylor (1972) and Salazar (1983) with exception of number and location of secondary constriction.

75. *Pinus ponderosa* Laws., 2n=24, Fig. 73

The seeds collected at Falkland, British Columbia, Canada (Table 1) were germinated and their root tips were used for cytological observation. All materials showed the chromosome number of 2n=24, which confirmed the previous reports by Sax & Sax (1933), Mehra & Khoshoo (1956), Saylor (1972) and Price *et al.* (1973).

The chromosomes at interphase (Fig. 73A) and mitotic prophase (Fig. 73B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. A degradation in size from the longest chromosome of 14.0 μm to the shortest chromosome of 9.1 μm was observed in the mitotic metaphase complement. Thus, the chromosomes formed highly homogeneous com-

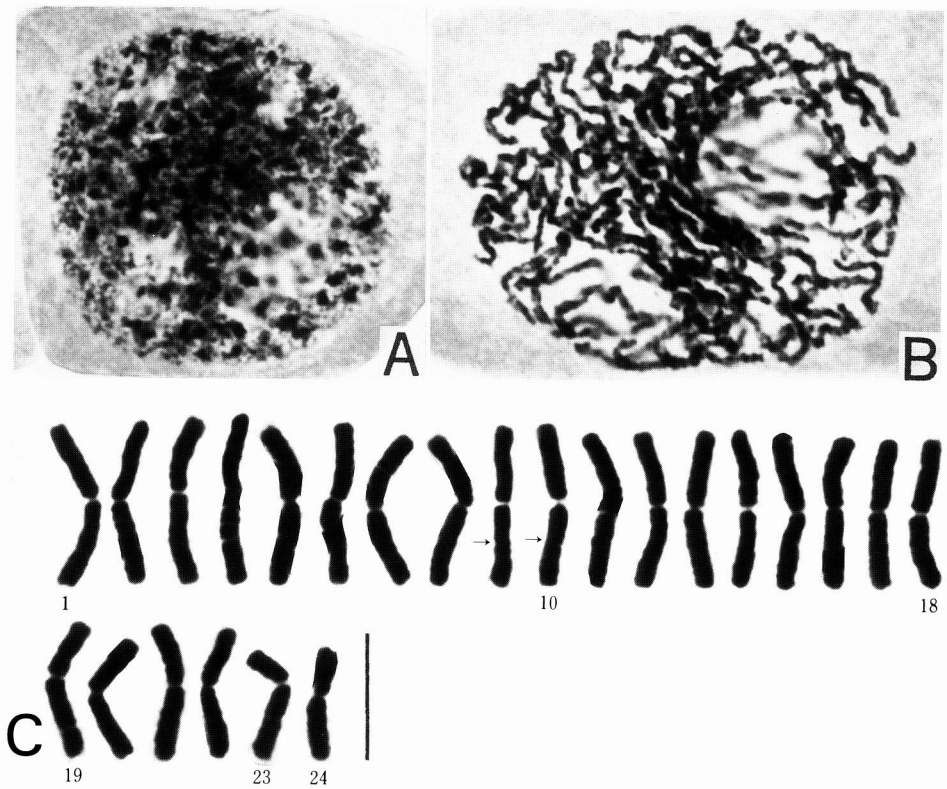

Fig. 73. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus ponderosa* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

plement. The pair of the shortest chromosomes decreased hastily in length. The chromosomes had the centromeres located at median regions excepting for the pair of the shortest chromosomes had the centromere located at median-submedian or submedian region (Fig. 73C). The chromosomes formed highly symmetrical complement. Secondary constrictions were observed on several pairs of chromosomes but their locations were not determined during the course of observation. The karyotype at mitotic metaphase is essentially similar to that reported by Sax & Sax (1933), Mehra & Khoshoo (1956) and Saylor (1972).

76. *Pinus jeffreyi* Grev. & Balf., 2n=24, Fig. 74

The seeds obtained from U.S.A. (Table 1) were germinated and their root tips were used for cytological observation. The chromosome number for this species was counted to be 2n=24, which confirmed the previous documents by Sax & Sax (1933) and Saylor (1972).

The chromosomes at interphase (Fig. 74A) and mitotic prophase (Fig. 74B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex

Fig. 74. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus jeffreyi* (2n = 24). Bar indicates 10 μm and arrows indicate secondary constrictions.

chromocenter type and the continuous type, respectively. In the mitotic metaphase complement the chromosomes varied gradually in length from 13.5–7.9 μm and formed highly homogeneous complement. The pair of the shortest chromosomes decreased hastily in length. Centromeres were located at median regions of most of the chromosomes and at submedian region in the pair of the shortest chromosomes (Fig. 74C). The chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial region of one of their arms on five pairs (the 2nd, 3rd, 4th, 5th, 11th) of metacentric chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Sax & Sax (1933) and Saylor (1972) with exception of number and location of secondary constriction.

77. *Pinus torreyana* Parry, 2n=24, Fig. 75

The seeds obtained from U.S.A. (Table 1) were germinated and their root tips were used for cytological observation. All plants showed the chromosome number of 2n=24, which confirmed the previous count by Saylor (1972).

The chromosomes at interphase (Fig. 75A) and mitotic prophase (Fig. 75B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. At mitotic metaphase the chro-

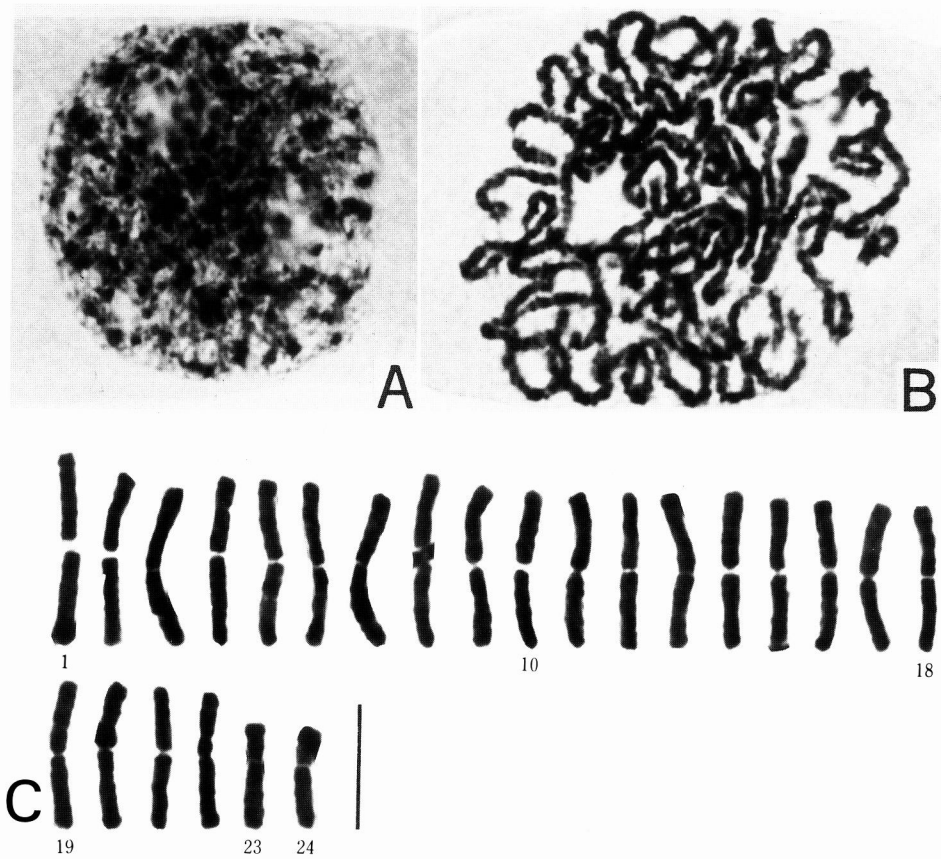

Fig. 75. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus torreyana* (2n = 24). Bar indicates 10 μm.

mosomes in each complement varied gradually in length from 14.5–8.1 μm and formed highly homogeneous complement. The pair of the shortest chromosomes decreased hastily in length. Centromeres were located at median regions of most of the chromosomes and at submedian region in the pair of the shortest chromosomes (Fig. 75C). The chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial region of one of the arms of several metacentric chromosomes but their locations were not determined. The karyotype at mitotic metaphase is essentially similar to that reported by Saylor (1972).

78. *Pinus banksiana* Lamb., 2n=24, Fig. 76

Five two-years-old plants (Table 1) were used for cytological observation. The chromosome number was counted to be 2n=24 in the five plants. This result confirms the previous documents by Sax & Sax (1933), Beal (1934), Sarker (1963), Kuroki (1969), Saylor (1972), Kormutak (1975), Karnosky & Setliff (1977) and Baranec (1979).

The chromosomes at interphase (Fig. 76A) and mitotic prophase (Fig. 76B) were very

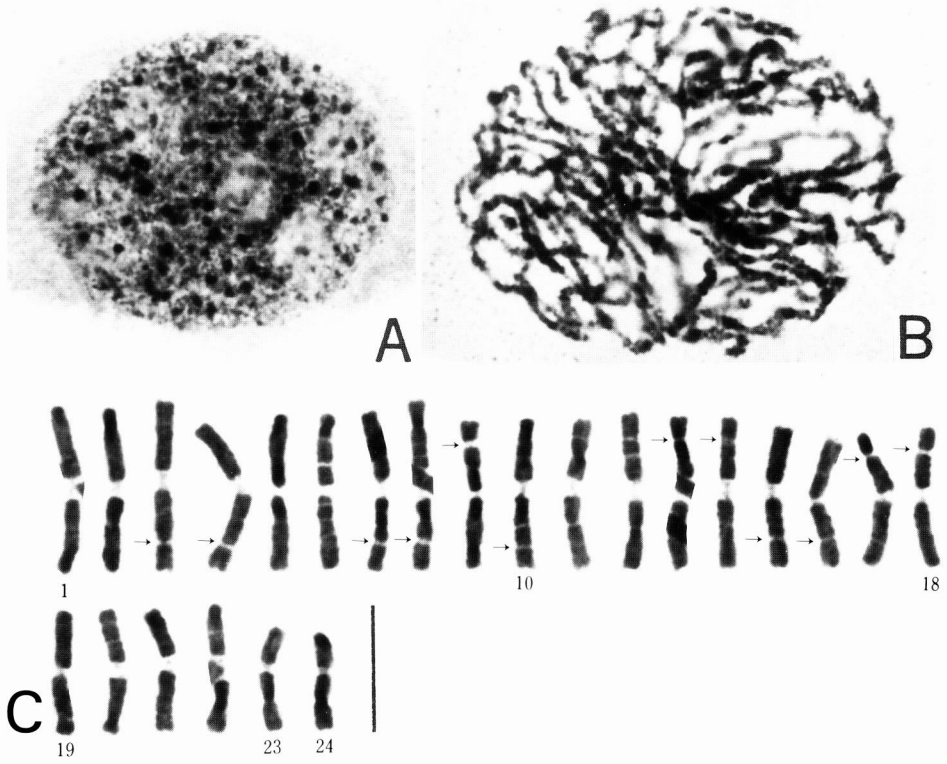

Fig. 76. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus banksiana* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase complement the chromosomes varied gradually in length from 12.2–7.7 μm and formed highly homogeneous complement. The pair of the shortest chromosomes decreased hastily in length. Centromeres were located at median regions in most of the chromosomes and at submedian region in the pair of the shortest chromosomes (Fig. 76C). The chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of their arms on six pairs (the 2nd, 4th, 5th, 7th, 8th, 9th) of metacentric chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Sax & Sax (1933), Sarker (1963), Kuroki (1969), Saylor (1972), Kormutak (1975) and Baranec (1979) with exception of number and location of secondary constriction.

79. *Pinus contorta* var. *contorta* Dougl., 2n=24, Fig. 77

The seeds collected in Richimond, British Columbia, Canada were germinated for cytological observation. The chromosome number was counted to be 2n=24 in all plants, which confirmed the previous documents by Saylor (1972), Kormuták (1975) and Teoh & Rees (1976).

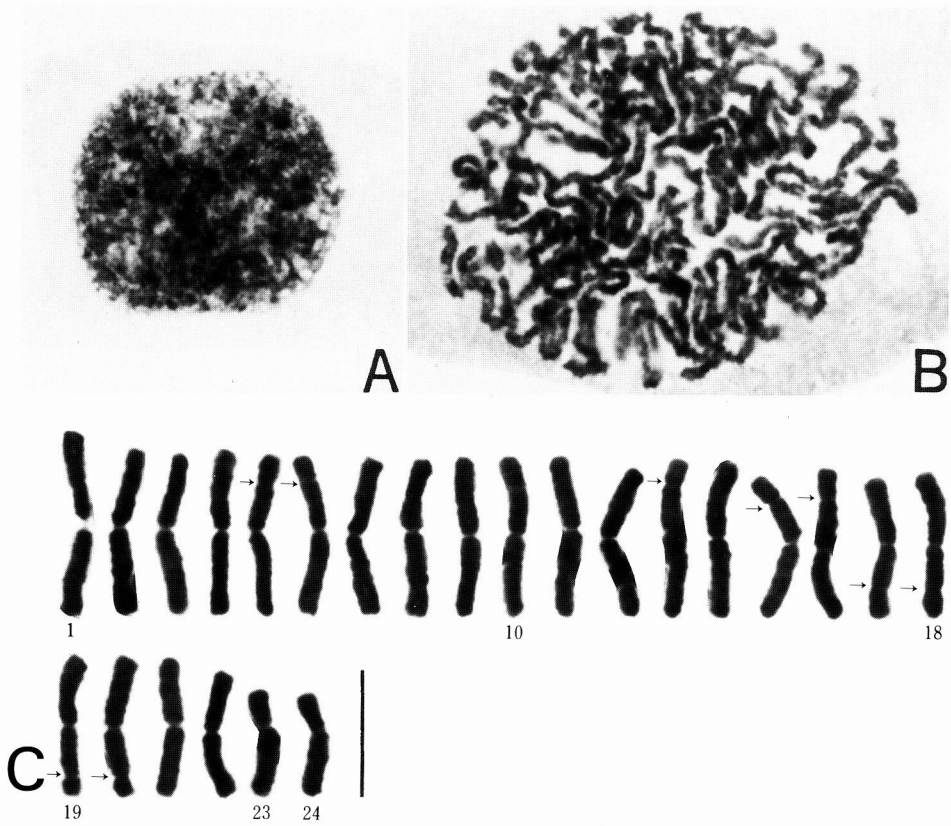

Fig. 77. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus contorta* var. *contorta* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes at interphase (Fig. 77A) and mitotic prophase (Fig. 77B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In mitotic metaphase plate the chromosomes varied gradually in length from 12.8–8.9 μm and formed highly homogeneous complement. The pair of the shortest chromosome decreased hastily in length. Centromeres were located at median regions in most of the chromosomes and at submedian region in the pair of the shortest chromosomes (Fig. 77C). The chromosomes formed highly symmetrical complement. Secondary constrictions were frequently observed at interstitial regions of one of their arms on five pairs (the 3rd, 7th, 8th, 9th, 10th pairs) of metacentric chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Saylor (1972) and Kormuták (1975) with exception of number and location of secondary constriction.

80. *Pinus contorta* var. *murrayana* Engelm., 2n=24, Fig. 78

The seeds obtained from Canada (Table 1) were germinated for cytological observa-

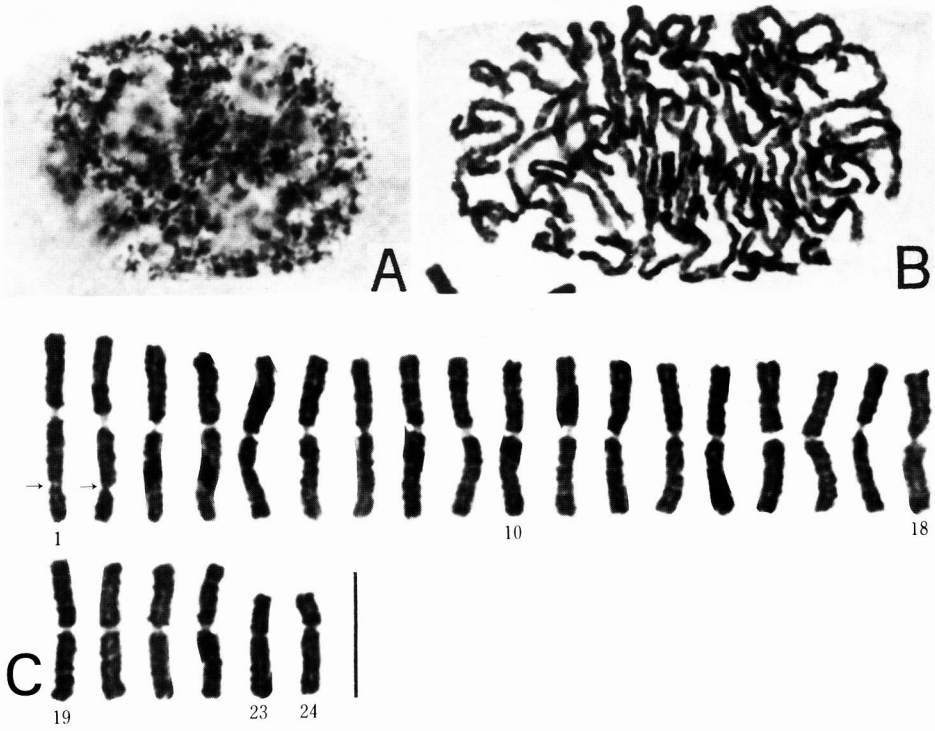

Fig. 78. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus contorta* var. *murrayana* (2n=24). Bar indicates 10 μm and arrows indicate secondary constrictions.

tion. The chromosome number of 2n=24 was counted here for the first time.

The chromosomes at interphase (Fig. 78A) and mitotic prophase (Fig. 78B) were very similar in karyomorphology to those in *P. contorta* var. *contorta*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase complement the chromosomes varied gradually in length from 12.8–8.9 μm and formed highly homogeneous complement. The pair of the shortest chromosomes decreased hastily in length. Centromeres were located at median regions in most of the chromosomes and at submedian region in the pair of the shortest chromosomes (Fig. 78C). The chromosomes formed highly symmetrical complement. Secondary constrictions were observed at interstitial region of one of the arms constantly on the 1st pair of chromosomes and often but not constantly on several other pairs which were not determined.

81. *Pinus virginiana* Mill., 2n=24, Fig. 79

The seedlings from the seeds collected at York, South Carolina, U.S.A. and three young plants (Table 1) were used for cytological observation. The chromosome number was counted to be 2n=24 in all plants, which confirmed the previous documents by Sax & Sax (1933), Saylor (1961, 1972) and Moromizato (1975).

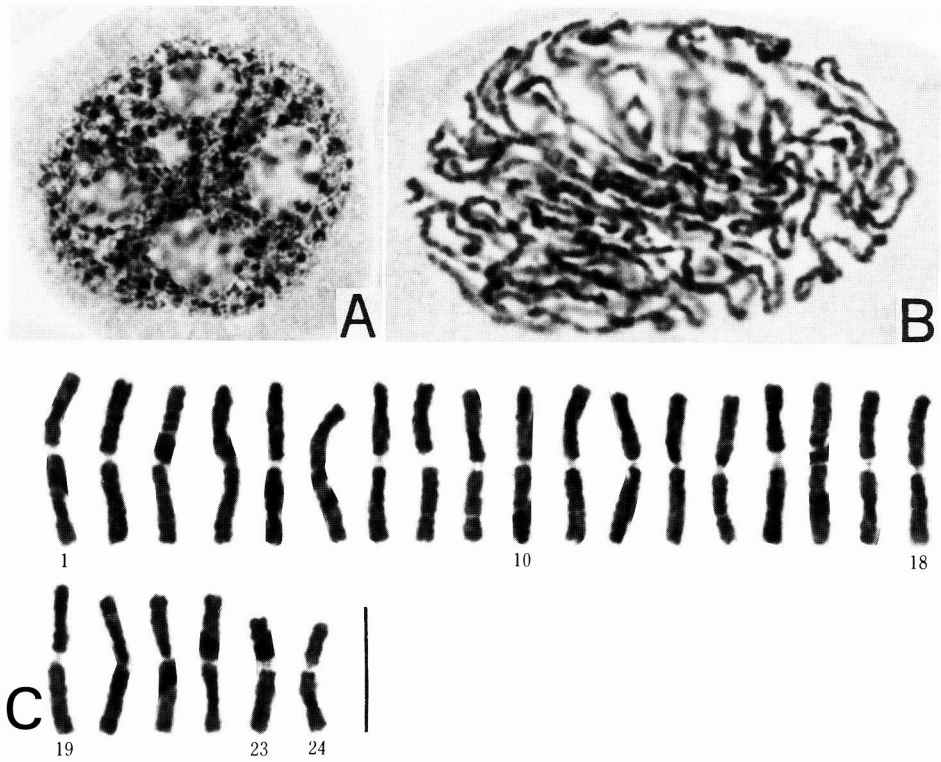

Fig. 79. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus virginiana* (2n=24). Bar indicates 10 μm.

The chromosomes at interphase (Fig. 79A) and mitotic prophase (Fig. 79B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. A degradation in size from the longest chromosome of 11.7 μm to the shortest chromosome of 7.6 μm was observed in the mitotic metaphase karyotype which formed highly homogeneous complement. The pair of the shortest chromosomes decreased hastily in length. Centromeres were located at median regions in most of the chromosomes and at median–submedian region in the pair of the shortest chromosomes (Fig. 79C). The chromosomes formed highly symmetric complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms of several metacentric chromosomes but their locations were not determined. The karyotype at mitotic metaphase is essentially similar to that reported by Sax & Sax (1933), Saylor (1961, 1972) and Moromizato (1975).

82. *Pinus muricata* D. Don, 2n=24, Fig. 80

The chromosome number was counted to be 2n=24 in the three plants studied. This result confirms the previous documents by Pederick (1970) and Saylor (1972).

The chromosomes at interphase (Fig. 80A) and mitotic prophase (Fig. 80B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex

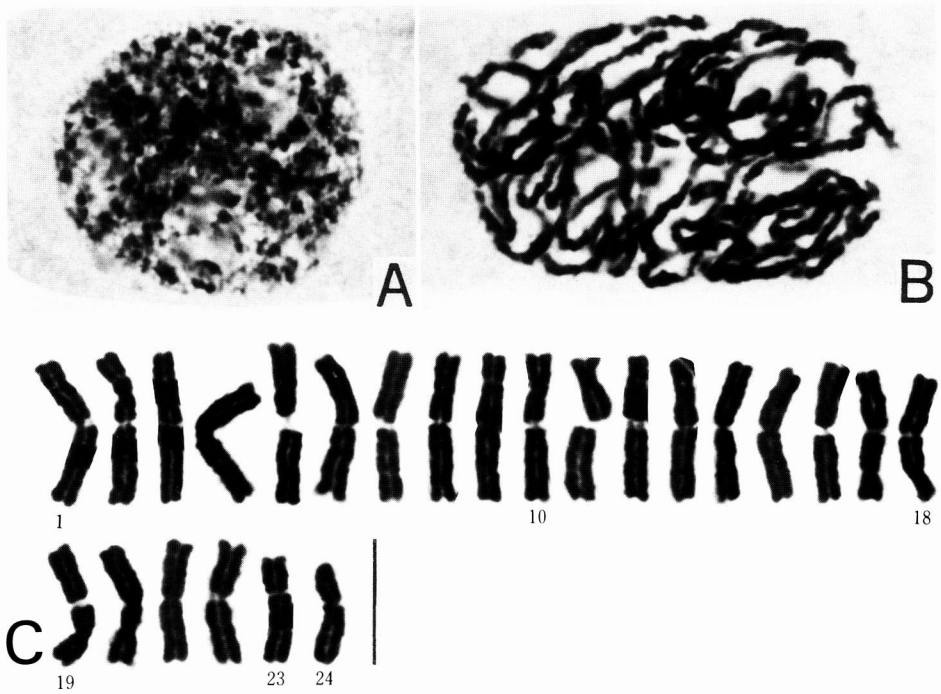

Fig. 80. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus muricata* (2n=24). Bar indicates 10 μm.

chromocenter type and the continuous type, respectively. In the mitotic metaphase complement the chromosomes varied gradually in length from 13.1–8.3 μm and formed highly homogeneous complement. The pair of the shortest chromosomes decreased hastily in length. Centromeres were located at median regions in most of the chromosomes and at submedian region in the pair of the shortest chromosomes (Fig. 80C). The chromosomes formed highly symmetric complement. Secondary constrictions were frequently observed at interstitial regions of one of the arms of several metacentric chromosomes but their locations were not determined. The karyotype at mitotic metaphase is essentially similar to that reported by Pederick (1970) and Saylor (1972).

83. *Pinus greggii* Engelm., 2n=24, Fig. 81

The seeds (Table 1) were germinated and their roots were used for cytological observation. The chromosome number of 2n=24 was shown in all seedlings studies. This result confirms the previous reports by Pederick (1970) and Saylor (1972).

The chromosomes at interphase (Fig. 81A) and mitotic prophase (Fig. 81B) were very similar in karyomorphology to those in *P. strobus*. They are categorized to be the complex chromocenter type and the continuous type, respectively. In the mitotic metaphase complement the chromosomes varied gradually in length from 15.6–9.7 μm and formed highly homogeneous complement. The pair of the shortest chromosome decreased hastily in length.

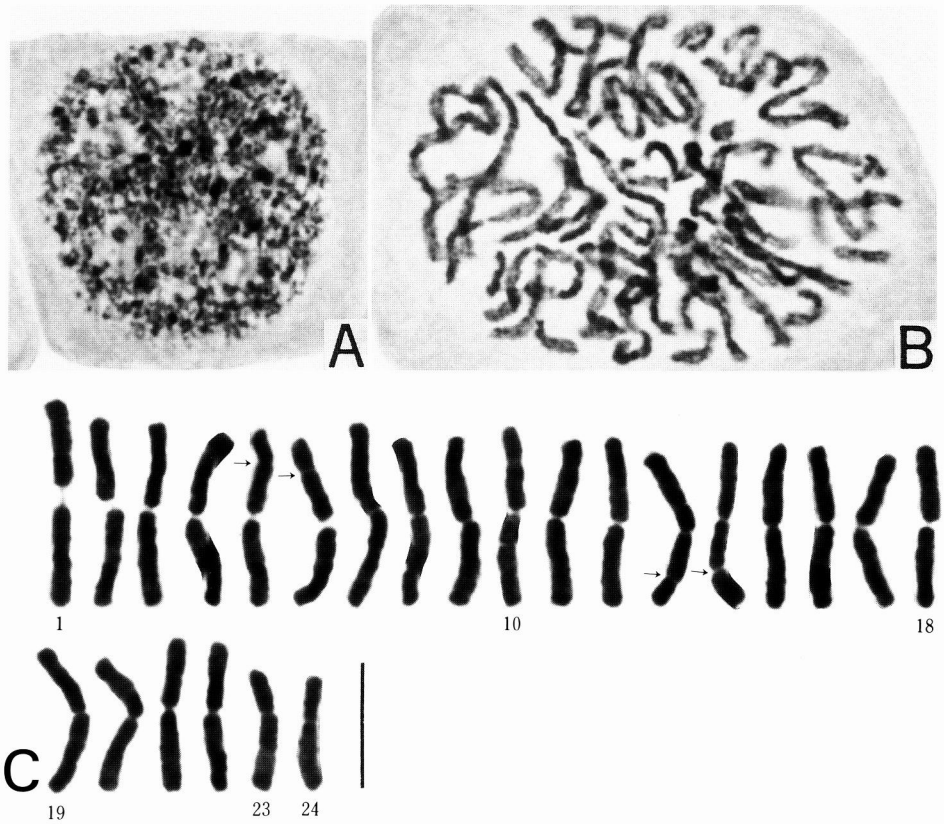

Fig. 81. Photomicrographs of chromosomes at interphase (A), mitotic prophase (B) and metaphase (C) in the root tip cells of *Pinus greggii* (2n = 24). Bar indicates 10 μm and arrows indicate secondary constrictions.

The chromosomes had the centromeres located at median regions except for a pair of the shortest chromosomes had a centromere at median-submedian or submedian region (Fig. 81C). The chromosomes formed highly symmetric complement. Secondary constrictions were frequently observed at interstitial regions of one of their arms on two pairs (the 3rd, 7th) of metacentric chromosomes. The karyotype at mitotic metaphase is essentially similar to that reported by Pederick (1970) and Saylor (1972) with exception of number and location of secondary constriction.

Discussion

Somatic chromosome numbers in about 180 species, nine genera in the Pinaceae have been reported (*e.g.*, Khoshoo 1961, Mehra 1968) resulting the stable somatic chromosome number of 2n=24 except for 2n=26 of *Pseudotsuga menziesii* and 2n=44 of *Pseudolarix kaempferi*. Moreover natural polyploids (Kanezawa 1949, Christiansen 1950, Kiellander 1950, Knaben 1953, Manzos & Pozdnjakov 1960, Zinnai 1952, Mergen 1958, Khoshoo 1959,

Nishimura 1960), haploids (Illies 1964), and aneuploids (Owens 1967, Johnson & Saylor 1973, Rehfeldt *et al.* 1983) have been rarely discovered. Since most of the species of the Pinaceae exhibited the same chromosome number of 2n=24, their karyotypes have had to be analyzed for comparisons among the species.

Karyomorphology of interphase chromosomes and condensation pattern of mitotic prophase chromosomes, which are better characters to group high cytotaxonomic ranks than chromosome number and karyotype, have become the important characters in the Orchidaceae and the Magnoliaceae (Tanaka 1977). In the gymnosperms the interphase nuclei and the prophase chromosomes had not been observed in detail. Thus, in this paper karyomorphology of the chromosomes at interphase and prophase in many species of the Pinaceae were observed and documented for the first time. The chromosomes at interphase are considered to be the complex chromocenter type. Heteropycnotic bodies varied in number among the genera of the Pinaceae. A number of heteropycnotic bodies was observed more often in the genera of *Pinus*, *Picea*, *Cedrus*, *Abies* and *Keteleeria* than in *Larix*, *Pseudotsuga* and *Pseudolarix*. The mitotic prophase chromosomes were observed in all species examined to condense homogeneously. Since distribution pattern of chromosomes at interphase and condensing pattern of chromosomes at mitotic prophase are very similar among the species and the genera, it is concluded, however, that these karyomorphological characters seem to be not important in the Pinaceae. Therefore, the chromosomes at mitotic metaphase are discussed in detail as follows:

The chromosomes at mitotic metaphase were rod-shaped and relatively long. The longest chromosome among the somatic metaphase chromosomes of all species studied was observed in *Pinus yunnanensis* and the shortest chromosomes in *Pseudolarix kaempferi*. The centromeres were located not at subterminal region but at median to submedian regions of the chromosomes of the species excepting for those were located at terminal regions of the chromosomes of only two species, *Pseudotsuga menziesii* and *Pseudolarix kaempferi*. Generally karyotypes of the Pinaceae appeared to be highly symmetrical. *Pinus*, *Picea*, and *Abies* displayed more secondary constrictions than *Pseudolarix*, *Larix*, *Pseudotsuga* and *Keteleeria* did. Most of the secondary constrictions were located at interstitial regions of the chromosomes. In a few species such as *Larix laricina*, *Pseudotsuga menziesii* and *Pseudolarix kaempferi* the secondary constrictions were located at proximal regions of the chromosomes. Terminal secondary construction which formed a small satellite had been frequently observed in *Ginkgo biloba* (Tanaka *et al.* 1952, Newcomer 1954, Lee 1954), *Ephedra* (Hunziker 1955) and cycads (Abraham & Mathew 1962, Marchant 1968) but was not observed at all in the Pinaceae examined. Although the genera of *Pinus*, *Picea* and *Abies* had many secondary constrictions in their chromosomes, numbers and locations of their secondary constrictions were different from each other. In fact, it was difficult to determine location of all of the secondary constrictions given. More critical observation using the differential staining method could be necessary to clearly detect secondary constrictions.

Concluding the results in 83 taxa in the present observation and the previous results, most of the genera in the Pinaceae have constant karyotypes although some genera have interspecific variations of karyotypes. In *Pseudotsuga* six species showed the common karyotype with 2n=24; six pairs of large metacentric chromosomes and six pairs of medium-sized submetacentric chromosomes but a species of *P. menziesii* showed different karyotype with 2n=26; same chromosomes as those of the former six species except for two pairs of telocentric chromosomes in place of a pair of large chromosomes.

In all species in *Larix* studied the karyotype was composed of six pairs of large metacentric chromosomes and six pairs of small submetacentric chromosomes. In respect to the secondary constrictions three types were classified during the course of this study in *Larix*: The first type of *L. leptolepis*, *L. occidentalis* and *L. potaninii* had four secondary constrictions at interstitial regions of two pairs of large metacentric chromosomes. The second type of *Larix decidua* and *L. gmelinii* had additional secondary constriction at interstitial region of long arm of a pair of submetacentric chromosomes while the third type of *L. laricina* had the secondary constriction at proximal region of a pair of large metacentric chromosomes. Simak (1966) has reported that the chromosomes of *L. griffithiana* have only two secondary constrictions at interstitial region of a pair of large metacentric chromosomes. Therefore, four karyotypes are present in *Larix* in respect to secondary constriction.

Among the genera in the Pinaceae studied, *Pinus* showed the most symmetric karyotype. Thus, two kinds of karyotypes were distinguished in *Pinus*; one type was composed of 11 pairs of large metacentric chromosomes and a pair of small meta-submetacentric or submetacentric chromosomes and the other type was composed of ten pairs of large metacentric chromosomes and two pairs of small asymmetric chromosomes. The latter karyotype was observed in 11 taxa; *P. nigra*, *P. sylvestris*, *P. densiflora*, *P. thunbergii*, *P. luchuensis*, *P. resinosa*, *P. yunnanensis*, *P. stankewiczii*, *P. brutia*, *P. pinaster*, and *P. khasya*. These species belong to subsection *Sylvestres* (Critchfield & Little 1966). This observation is coincided to the report by Saylor (1964).

According to morphological observation on chromosomes at mitotic metaphase, the karyotypes observed in the Pinaceae are divided into seven types as follows:

Type 1. The chromosome number is 2n=24. The karyotype is composed of many large metacentric chromosomes and one or two pairs of smaller meta-submetacentric or submetacentric chromosomes. This type is observed in *Pinus* and is the most symmetric among the types.

Type 2. The chromosome number is 2n=24. The karyotype consists of nine pairs of large metacentric chromosomes and three pairs of medium-sized submetacentric chromosomes. This type is observed in *Cedrus*.

Type 3. The chromosome number is 2n=24. The karyotype consists of eight pairs of large metacentric chromosomes and four pairs of medium-sized chromosomes. This type is observed in *Picea* and *Tsuga*.

Type 4. The chromosome number is 2n=24. The karyotype is composed of seven pairs of large metacentric chromosomes and five pairs of medium-sized submetacentric chromosomes and indicates clearly bimodality. This type is observed in *Abies* and *Keteleeria*.

Type 5. The chromosome number is 2n=24. The karyotype is composed of six pairs of large metacentric chromosomes and six pairs of medium-sized submetacentric chromosomes and shows clearly bimodality. This type is observed in *Larix* and most species of *Pseudotsuga*.

Type 6. The chromosome number is 2n=26. The karyotype consists of five pairs of large metacentric chromosomes, six pairs of medium-sized submetacentric chromosomes and two pairs of small telocentric chromosomes. This karyotype is observed only in *Pseudotsuga menziesii*.

Type 7. The chromosome number is 2n=44. The karyotype is composed of two pairs of medium-sized submetacentric and 20 pairs of small telocentric chromosomes and is clearly bimodal. The karyotype is the most asymmetrical. This type is observed only in *Pseudolarix kaempferi*.

Small telocentric chromosomes appeared only in *Pseudotsuga menziesii* and *Pseudolarix kaempferi* characterized by more chromosome number than 2n=24. Telocentric chromosomes are shorter than one-side arms of large metacentric chromosomes. If two telocentric chromosomes were derived from one meta- or submeta-centric chromosomes by centromeric fission, the original chromosome number should be speculated to be 2n=24.

The above grouping of the karyotypes given is compared with the taxonomic treatment of Pilger & Melchior (1954). Type 1 is compatible with subfamily Pinoideae, Types 3, 4, 6 and a part of Type 5 with subfamily Abietoideae and Types 2, 7 and the other part of Type 5 with subfamily Laricoideae. Taxonomic treatment of *Pseudotsuga* and *Cedrus* is not followed by the grouping of karyotypes. Karyomorphological similarity between *Larix* and *Pseudotsuga* is compatible with the phylogenetic study by Flous (1936) and the immunological analysis by Prager *et al.* (1976). These two genera have distinct pollination mechanism with special shaped stigma (Doyle 1945, Christiansen 1972). *Abies* is taxonomically mentioned to be the most closely related to *Keteleeria* (Liu 1971). These two genera belong to Type 4. *Picea* and *Tsuga* are placed in Type 3. This phenomenon is supported by occurrence of intergeneric hybrids between two genera (Campo-Duplan & Gaussen 1949, Durrieu-Vabre 1954). *Cathaya* is a monotypic genus growing only in the People's Republic of China. Its chromosomes have not been investigated at present. Karyological studies on *Cathaya* is desired in order to understand phylogenetic relationships among the genera of the Pinaceae.

It is necessary to study in detail on relationships among the species and the genera with respect to karyotype. For analysis of same or similar karyotypes the differential staining, which can detect the specific chromosomal segment by certain bands, seems to be very useful. Up to this point in the Pinaceae C-banding (Borzan & Papeš 1978, Tanaka &

Hizume 1980, Wochok *et al.* 1980, MacPherson & Filion 1981 and Tong & Hao 1986), fluorescent banding (Hizume *et al.* 1982, 1983), G-banding (Kupila-Ahvenniemi & Hohtola 1977, Wochok *et al.* 1980, Drewry 1982, Chen *et al.* 1986, Xia & Liao 1986) have been reported. Most of these studies have been yet staying in preliminary step. Application of the differential staining method to certain chromosomes, many species in the Pinaceae could be expected to understand relationships among the species and the genera in the Pinaceae.

Summary

1. The chromosomes at interphase and mitotic prophase and metaphase in somatic cells of nine genera, 83 taxa (76 species and seven varieties) in the Pinaceae were karyomorphologically studied. Morphological characteristics of chromosomes were described in respect to morphology of chromatin at interphase, location of early and late condensing regions at mitotic prophase, and chromosome number, length of chromosomes, position of centromere (arm ratio), secondary constriction, small constriction and so on at mitotic metaphase. The photomicrographs and tables of chromosome measurements at mitotic metaphase were documented.

2. The chromosome numbers of the species studied were all 2n=24, except for those of two species, *Pseudotsuga menziesii* 2n=26 and *Pseudolarix kaempferi* 2n=44. The chromosome counts in 74 taxa confirmed the previous reports. The chromosome numbers of five genera, nine taxa, *Abies ernestii* 2n=24, *Abies veitchii* var. *sikokiana* 2n=24, *Abies mariesii* 2n=24, *Keteleeria davidiana* 2n=24, *Picea polita* 2n=24, *Larix potaninii* 2n=24, *Larix gmelinii* var. *japonica* 2n=24, *Pinus stankewiczii* 2n=24, and *Pinus contorta* var. *murrayana* 2n=24 were reported here for the first time.

3. The chromosomes at interphase appeared as several spherical heteropycnotic bodies and dispersed as many chromomeric granules and fibrous chromosome fibers. Morphology of chromosomes at interphase was similar among all taxa and was categorized to be the complex chromocenter type. The heteropycnotic bodies in *Pinus*, *Picea*, *Abies* and *Keteleeria* were larger in number than in *Larix*, *Pseudotsuga* and *Pseudolarix*.

4. The chromosomes at mitotic prophase were condensing homogeneously along a long axis in all taxa. Morphology of mitotic prophase chromosomes was categorized to be the continuous type.

5. The chromosomes at metaphase were rod-shaped and relatively long. On the basis of chromosome length, location of centromere and secondary constriction, karyotypes of 29 taxa in six genera were firstly described, that of one taxon was similar but not same to the previous reports and those of 53 taxa confirmed the previous reports. Most of the genera showed stable, common karyotypes at mitotic metaphase with a little differences.

6. Chromosomes with secondary constriction were observed in many taxa. Number of secondary constrictions per chromosome complement in *Pinus* and *Picea* was more than that

in *Larix*, *Pseudolarix*, *Pseudotsuga*, *Keteleeria*. In this study, 25 taxa in six genera displayed firstly the secondary constrictions, while 34 taxa in four genera displayed somewhat similar but different secondary constrictions from those of the previous reports and three taxa in two genera confirmed those of the previous reports. Most of the secondary constrictions were located at interstitial regions of chromosomes and a few at proximal regions.

7. According to chromosome morphology at mitotic metaphase, the karyotypes observed in the Pinaceae were grouped into seven types as follows:

Type 1. The chromosome number was 2n=24. The karyotype was composed of many large metacentric chromosomes and one or two pairs of smaller chromosomes with median–submedian or submedian centromere. The karyotype was the most symmetrical. This type was observed in *Pinus*.

Type 2. The chromosome number was 2n=24. The karyotype consisted of nine pairs of large metacentric chromosomes and three pairs of medium-sized submetacentric chromosomes. This type was observed in *Cedrus*.

Type 3. The chromosome number was 2n=24. The karyotype was composed of eight pairs of large metacentric chromosomes and four pairs of medium-sized chromosomes. This type was observed in *Picea* and *Tsuga*.

Type 4. The chromosome number was 2n=24. The karyotype consisted of seven pairs of large metacentric chromosomes and five pairs of medium-sized submetacentric chromosomes and thus, showed clearly bimodality. This type was observed in *Abies* and *Keteleeria*.

Type 5. The chromosome number was 2n=24. The karyotype consisted of six pairs of large metacentric chromosomes and six pairs of medium-sized submetacentric chromosomes and thus, showed clearly bimodality. This type was observed in *Larix* and most of the species of *Pseudotsuga*.

Type 6. The chromosome number was 2n=26. The karyotype was composed of five pairs of large metacentric chromosomes, six pairs of medium-sized submetacentric chromosomes and two pairs of small telocentric chromosomes. This karyotype was observed only in *Pseudotsuga menziesii*.

Type 7. The chromosome number was 2n=44. The karyotype was composed of two pairs of medium-sized submetacentric and 20 pairs of small telocentric chromosomes, and thus was clearly bimodal. This karyotype was the most asymmetrical and was observed only in *Pseudolarix*.

8. The above grouping of karyotypes was compared with the taxonomic treatment of Pilger & Melchior (1954). Type 1 was compatible with Pinoideae, Types 3, 4, 6 and a part of Type 5 with Abietoideae and Types 2, 7 and the other parts of Type 5 with Laricoideae. Taxonomic treatment of *Pseudotsuga* and *Cedrus* was not followed by the grouping of karyotypes. Karyomorphological similarity between *Larix* and *Pseudotsuga* was compatible with the taxonomic treatments of Flous (1936), Doyle (1945) and Prager *et al.* (1976).

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Table 2. Measurements of somatic chromosomes at metaphase in *Abies concolor*

Chromosome	Long arm length (μm)	Short arm length (μm)	Total length (μm)	Relative length (%)	Arm ratio	Form
1	6.7	4.9+1.8	13.4	5.3	1.0	m
2	6.9	4.5+2.0	13.4	5.3	1.1	m
3	1.8+4.8	6.2	12.8	5.1	1.1	m
4	1.7+4.9	5.9	12.5	4.9	1.1	m
5	6.5	3.7+2.2	12.4	4.9	1.1	m
6	6.4	3.9+1.8	12.1	4.8	1.1	m
7	2.3+3.9	5.9	12.1	4.8	1.1	m
8	2.0+4.4	5.3	11.7	4.6	1.2	m
9	5.8	5.7	11.5	4.5	1.0	m
10	6.0	5.4	11.4	4.5	1.1	m
11	6.0	5.4	11.4	4.5	1.1	m
12	5.7	5.6	11.3	4.5	1.0	m
13	5.9	5.2	11.1	4.4	1.1	m
14	5.9	5.0	10.9	4.3	1.2	m
15	6.8	2.9	9.7	3.8	2.3	sm
16	6.4	2.9	9.3	3.7	2.2	sm
17	6.6	2.5	9.1	3.6	2.6	sm
18	6.3	2.7	9.0	3.6	2.3	sm
19	6.3	2.6	8.9	3.5	2.4	sm
20	5.7	2.8	8.5	3.4	2.0	sm
21	5.4	2.8	8.2	3.2	1.9	sm
22	5.4	2.5	7.9	3.1	2.2	sm
23	4.7	2.6	7.3	2.9	1.8	sm
24	4.7	2.5	7.2	2.8	1.9	sm

Table 3. Measurements of somatic chromosomes at metaphase in *Keteleeria davidiana*

Chromosome	Long arm length (μm)	Short arm length (μm)	Total length (μm)	Relative length (%)	Arm ratio	Form
1	6.1	5.2	11.3	5.2	1.2	m
2	5.5	5.4	10.9	5.0	1.0	m
3	5.8	5.1	10.9	5.0	1.0	m
4	5.3	5.3	10.6	4.8	1.0	m
5	5.5	5.1	10.6	4.8	1.1	m
6	5.3	5.2	10.5	4.8	1.0	m
7	5.3	5.2	10.5	4.8	1.0	m
8	5.2	4.9	10.3	4.7	1.1	m
9	5.4	3.1+1.8	10.3	4.7	1.1	m
10	5.4	3.1+1.8	10.3	4.7	1.1	m
11	5.5	2.9+1.8	10.2	4.7	1.2	m
12	5.3	2.9+1.8	10.0	4.6	1.1	m
13	4.8	4.7	9.5	4.3	1.0	m
14	4.6	4.4	9.0	4.1	1.0	m
15	5.2	3.7	8.9	4.1	1.4	msm
16	5.2	3.2	8.4	3.8	1.6	msm
17	5.3	2.5	7.8	3.6	2.1	sm
18	5.5	2.3	7.8	3.6	2.4	sm
19	4.6	3.2	7.8	3.6	1.4	msm
20	4.5	3.1	7.6	3.5	1.6	msm
21	4.5	2.3	6.8	3.1	2.0	sm
22	4.3	2.3	6.6	3.0	1.9	sm
23	4.3	2.3	6.6	3.0	1.9	sm
24	4.1	2.3	6.4	2.9	1.8	sm

Table 4. Measurements of somatic chromosomes at metaphase in *Pseudotsuga menziesii*

Chromosome	Long arm length (μm)	Short arm length (μm)	Total length (μm)	Relative length (%)	Arm ratio	Form
1	5.8	5.7	11.5	5.8	1.0	m
2	5.5	5.4	10.9	5.5	1.0	m
3	5.4	5.4	10.8	5.4	1.0	m
4	4.5	5.1	10.5	5.3	1.1	m
5	5.3	5.0	10.3	5.2	1.1	m
6	4.8	4.7	9.5	4.8	1.0	m
7	4.8	2.9+1.8	9.5	4.8	1.0	m
8	4.8	2.9+1.8	9.5	4.8	1.0	m
9	4.8	4.5	9.3	4.7	1.1	m
10	4.7	4.4	9.1	4.6	1.1	m
11	5.1	2.4	7.5	3.8	2.1	sm
12	4.8	2.4	7.2	3.6	2.0	sm
13	5.0	2.0	7.0	3.5	2.5	sm
14	4.7	2.2	6.9	3.5	2.1	sm
15	4.3+0.5	2.1	6.9	3.5	2.0	sm
16	4.3+0.5	2.1	6.9	3.5	2.3	sm
17	4.5	1.9	6.4	3.2	2.4	sm
18	4.7	1.7	6.4	3.2	2.8	sm
19	4.0+0.5	1.8	6.3	3.2	2.5	sm
20	3.7+0.5	2.0	6.2	3.1	2.1	sm
21	4.5	1.7	6.2	3.1	2.4	sm
22	4.3	1.9	6.2	3.1	2.3	sm
23	5.2	0	5.2	2.6	–	t
24	4.9	0	4.9	2.5	–	t
25	4.4	0	4.4	2.2	–	t
26	4.2	0	4.2	2.1	–	t

Table 5. Measurements of somatic chromosomes at metaphase in *Pseudotsuga japonica*

Chromosome	Long arm length (μm)	Short arm length (μm)	Total length (μm)	Relative length (%)	Arm ratio	Form
1	6.0	5.5	11.5	5.4	1.1	m
2	5.9	5.5	11.4	5.4	1.1	m
3	5.7	5.5	11.2	5.3	1.0	m
4	5.7	5.3	11.0	5.2	1.1	m
5	1.9+6.0	5.0	11.0	5.2	1.2	m
6	2.0+5.4	5.3	10.9	5.2	1.0	m
7	5.8	4.8	10.6	5.0	1.2	m
8	5.3	5.3	10.6	5.0	1.0	m
9	5.6	3.4+1.6	10.6	5.0	1.1	m
10	5.4	3.5+1.7	10.6	5.0	1.0	m
11	5.2	5.1	10.3	4.9	1.0	m
12	4.9	4.8	9.7	4.6	1.0	m
13	5.3	2.2	7.5	3.5	2.4	sm
14	5.2	2.2	7.4	3.5	2.4	sm
15	5.3	1.9	7.2	3.4	2.8	sm
16	5.1	2.0	7.1	3.4	2.6	sm
17	4.9	2.2	7.1	3.4	2.2	sm
18	5.0	2.0	7.0	3.3	2.5	sm
19	4.9	2.1	7.0	3.3	2.3	sm
20	4.8	1.8	6.0	3.1	2.7	sm
21	4.4	2.1	6.5	3.1	2.5	sm
22	4.5	1.8	6.3	3.1	2.1	sm
23	4.5	1.8	6.3	3.0	2.5	sm
24	4.2	1.9	6.1	2.9	2.2	sm

Table 6. Measurements of somatic chromosomes at metaphase in *Tsuga canadensis*

Chromosome	Long arm length (μm)	Short arm length (μm)	Total length (μm)	Relative length (%)	Arm ratio	Form
1	5.6	5.2	10.8	5.1	1.1	m
2	5.6	4.6	10.2	4.8	1.2	m
3	5.8	4.4	10.2	4.8	1.3	m
4	5.6	4.6	10.2	4.8	1.2	m
5	2.0+3.5	4.6	10.1	4.8	1.2	m
6	2.0+3.3	4.8	10.1	4.8	1.1	m
7	5.1	4.8	9.9	4.7	1.1	m
8	5.0	4.9	9.9	4.7	1.0	m
9	5.2	4.3	9.5	4.5	1.2	m
10	5.2	4.3	9.5	4.5	1.2	m
11	5.1	4.2	9.3	4.4	1.2	m
12	5.4	3.8	9.2	4.4	1.4	m
13	4.5	2.7+1.8	9.0	4.3	1.0	m
14	4.4	2.6+1.8	8.8	4.2	1.0	m
15	5.1	3.3	8.4	4.0	1.5	msm
16	4.9	3.4	8.3	4.0	1.4	msm
17	5.4	2.5	7.9	3.8	2.2	sm
18	4.9	2.9	7.8	3.7	1.7	sm
19	4.8	2.5	7.3	3.5	1.9	sm
20	4.8	2.4	7.2	3.4	2.0	sm
21	3.6	3.6	7.2	3.4	1.0	m
22	3.6	3.5	7.1	3.4	1.0	m
23	4.1	2.2	6.3	3.0	1.9	sm
24	4.2	2.0	6.2	2.9	2.1	sm

Table 7. Measurements of somatic chromosomes at metaphase in *Picea abies*

Chromosome	Long arm length (μm)	Short arm length (μm)	Total length (μm)	Relative length (%)	Arm ratio	Form
1	6.5	6.3	12.8	5.1	1.0	m
2	6.1	6.0	12.1	4.9	1.0	m
3	6.0	4.0+1.6	11.6	4.7	1.1	m
4	5.8	3.8+1.6	11.6	4.7	1.0	m
5	5.8	5.8	11.6	4.7	1.0	m
6	5.8	5.6	11.4	4.6	1.0	m
7	5.9	5.5	11.4	4.6	1.1	m
8	5.8	5.6	11.4	4.6	1.0	m
9	2.5+3.3	5.4	11.2	4.5	1.1	m
10	2.5+3.3	5.3	11.1	4.5	1.1	m
11	5.9	3.1+2.1	11.1	4.5	1.1	m
12	5.8	2.9+2.1	10.8	4.3	1.1	m
13	3.3+2.9	4.3	10.5	4.2	1.4	msm
14	3.0+3.1	4.3	10.4	4.2	1.4	msm
15	5.4	5.0	10.4	4.2	1.1	m
16	5.2	3.5+1.7	10.4	4.2	1.0	m
17	5.2	3.3+1.9	10.4	4.2	1.0	m
18	5.3	2.2+1.9	9.4	3.8	1.3	m
19	5.6	3.6	9.2	3.7	1.6	msm
20	5.6	3.5	9.1	3.7	1.6	msm
21	4.7	3.7	8.4	3.4	1.3	m
22	4.6	3.6	8.2	3.3	1.3	m
23	4.8	2.4	7.2	2.9	2.0	sm
24	4.8	2.3	7.1	2.9	2.1	sm

Table 8. Measurements of somatic chromosomes at metaphase in *Pseudolarix kaempferi*

Chromosome	Long arm length (μm)	Short arm length (μm)	Total length (μm)	Relative length (%)	Arm ratio	Form
1	4.6	2.5	7.1	3.3	1.8	sm
2	4.4	2.5	6.9	3.2	1.8	sm
3	4.6	2.1	6.7	3.2	2.2	sm
4	4.6	2.1	6.7	6.2	2.2	sm
5	5.4+0.6	0	6.0	2.8	-	t
6	5.1+0.6	0	5.7	2.7	-	t
7	5.3	0	5.3	2.5	-	t
8	5.2	0	5.2	2.4	-	t
9	5.2	0	5.2	2.4	-	t
10	5.2	0	5.2	2.4	-	t
11	5.1	0	5.1	2.4	-	t
12	5.0	0	5.0	2.4	-	t
13	4.9	0	4.9	2.3	-	t
14	4.9	0	4.9	2.3	-	t
15	4.9	0	4.9	2.3	-	t
16	4.8	0	4.8	2.3	-	t
17	4.8	0	4.8	2.3	-	t
18	4.8	0	4.8	2.3	-	t
19	4.8	0	4.8	2.3	-	t
20	4.8	0	4.8	2.3	-	t
21	4.7	0	4.7	2.2	-	t
22	4.7	0	4.7	2.2	-	t
23	4.6	0	4.6	2.2	-	t
24	4.6	0	4.6	2.2	-	t
25	4.6	0	4.6	2.2	-	t
26	4.6	0	4.6	2.2	-	t
27	4.6	0	4.6	2.2	-	t
28	4.6	0	4.6	2.2	-	t
29	4.6	0	4.6	2.2	-	t
30	4.5	0	4.5	2.1	-	t
31	4.5	0	4.5	2.1	-	t
32	4.5	0	4.5	2.1	-	t
33	4.5	0	4.5	2.1	-	t
34	4.4	0	4.4	2.1	-	t
35	4.4	0	4.4	2.1	-	t
36	4.3	0	4.3	2.0	-	t
37	4.3	0	4.3	2.0	-	t
37	4.1	0	4.1	1.9	-	t
39	4.1	0	4.1	1.9	-	t
40	3.9	0	3.9	1.8	-	t
41	3.7	0	3.7	1.7	-	t
42	3.7	0	3.7	1.7	-	t
43	3.6	0	3.6	1.6	-	t
44	3.5	0	3.5	1.6	-	t

Table 9. Measurements of somatic chromosomes at metaphase in *Larix potaninii*

Chromosome	Long arm length (μm)	Short arm length (μm)	Total length (μm)	Relative length (%)	Arm ratio	Form
1	6.0	5.0	11.0	5.6	1.2	m
2	5.5	5.1	10.6	5.4	1.1	m
3	5.9	3.1+1.6	10.6	5.4	1.3	m
4	5.6	3.1+1.7	10.4	5.3	1.2	m
5	5.4	5.0	10.4	5.3	1.1	m
6	5.0	4.8	9.8	5.0	1.0	m
7	5.0	2.9+1.6	9.5	4.8	1.1	m
8	4.9	2.8+1.7	9.4	4.8	1.1	m
9	4.8	4.4	9.2	4.7	1.1	m
10	4.7	4.7	9.4	4.8	1.0	m
11	4.8	4.1	8.9	4.5	1.2	m
12	4.8	4.0	8.8	4.5	1.2	m
13	5.1	2.3	7.4	3.8	2.2	sm
14	5.3	1.8	7.1	3.6	2.9	sm
15	5.0	2.1	7.1	3.6	2.4	sm
16	4.9	2.1	7.0	3.6	2.3	sm
17	4.7	2.2	6.9	3.5	2.1	sm
18	4.6	1.9	6.5	3.3	2.4	sm
19	4.5	1.9	6.4	3.3	2.4	sm
20	4.3	2.0	6.3	3.2	2.2	sm
21	4.4	1.7	6.1	3.1	2.6	sm
22	4.3	1.8	6.1	3.1	2.4	sm
23	4.3	1.6	5.9	3.0	2.7	sm
24	4.1	1.7	5.8	3.0	2.4	sm

Table 10. Measurements of somatic chromosomes at metaphase in *Cedrus deodara*

Chromosome	Long arm length (μm)	Short arm length (μm)	Total length (μm)	Relative length (%)	Arm ratio	Form
1	5.9	3.1+2.2	11.2	4.9	1.1	m
2	5.5	3.3+2.2	11.0	4.8	1.0	m
3	2.8+3.0	5.2	11.0	4.8	1.1	m
4	2.8+2.9	5.1	10.8	4.7	1.1	m
5	5.4	5.1	10.5	4.6	1.1	m
6	5.5	4.9	10.4	4.5	1.1	m
7	3.8+1.5	5.1	10.4	4.5	1.0	m
8	3.8+1.5	4.9	10.2	4.4	1.1	m
9	5.3	4.9	10.2	4.4	1.1	m
10	5.2	4.6	9.8	4.2	1.1	m
11	5.0	4.7	9.7	4.2	1.1	m
12	4.9	4.8	9.7	4.2	1.0	m
13	5.0	4.6	9.6	4.2	1.1	m
14	5.0	4.6	9.6	4.2	1.1	m
15	4.8	4.7	9.5	4.1	1.0	m
16	5.0	4.1	9.1	4.0	1.2	m
17	4.9	4.0	8.9	3.9	1.2	m
18	4.4	4.3	8.7	3.8	1.0	m
19	5.5	3.2	8.7	3.8	1.7	sm
20	5.7	2.9	8.6	3.7	2.0	sm
21	5.4	2.9	8.3	3.6	1.9	sm
22	5.1	3.0	8.1	3.6	1.7	sm
23	4.7	2.8	7.5	3.3	1.7	sm
24	4.5	2.7	7.2	3.1	1.7	sm

Table 11. Measurements of somatic chromosomes at metaphase in *Pinus strobus*

Chromosome	Long arm length (μm)	Short arm length (μm)	Total length (μm)	Relative length (%)	Arm ratio	Form
1	7.9	4.3+2.6	14.8	4.9	1.1	m
2	7.5	4.4+2.6	14.5	4.8	1.1	m
3	7.3	7.1	14.4	4.7	1.0	m
4	7.5	6.4	13.9	4.6	1.2	m
5	3.2+4.1	6.2	13.5	4.5	1.2	m
6	3.1+4.1	6.3	13.5	4.5	1.0	m
7	7.1	6.4	13.5	4.5	1.1	m
8	7.3	6.1	13.4	4.4	1.2	m
9	6.7	6.6	13.3	4.4	1.0	m
10	6.5	6.5	13.0	4.3	1.0	m
11	6.6	3.9+2.5	13.0	4.3	1.0	m
12	6.5	3.5+2.6	12.6	4.2	1.1	m
13	6.3	6.3	12.6	4.2	1.0	m
14	6.5	6.0	12.5	4.1	1.1	m
15	6.5	6.0	12.5	4.1	1.1	m
16	6.4	6.0	12.4	4.1	1.1	m
17	6.6	3.5+1.9	12.0	3.9	1.2	m
18	6.2	3.9+1.7	11.8	3.8	1.1	m
19	6.1	5.7	11.8	4.0	1.1	m
20	5.9	5.7	11.6	3.8	1.0	m
21	6.2	4.1+1.3	11.6	3.8	1.2	m
22	5.9	5.1+1.4	11.4	3.8	1.1	m
23	6.1	4.1	10.2	3.4	1.5	msm
24	5.6	3.9	9.5	3.1	1.4	msm

Table 12. Measurements of somatic chromosomes at metaphase in *Pinus resinosa*

Chromosome	Long arm length (μm)	Short arm length (μm)	Total length (μm)	Relative length (%)	Arm ratio	Form
1	6.8	6.8	13.6	4.8	1.0	m
2	6.8	6.8	13.6	4.8	1.0	m
3	3.2+3.5	6.2	12.9	4.6	1.1	m
4	3.3+3.5	6.1	12.9	4.6	1.1	m
5	6.9	6.0	12.9	4.6	1.2	m
6	6.8	6.1	12.9	4.6	1.1	m
7	6.6	5.7	12.3	4.4	1.2	m
8	6.2	6.1	12.3	4.4	1.0	m
9	6.4	3.1+2.8	12.3	4.4	1.1	m
10	6.4	3.5+2.3	12.2	4.3	1.1	m
11	6.3	5.8	12.1	4.3	1.1	m
12	6.2	5.9	12.1	4.3	1.1	m
13	4.8+1.8	5.4	12.1	4.3	1.2	m
14	4.7+1.9	5.4	12.1	4.3	1.2	m
15	6.1	6.0	12.1	4.3	1.0	m
16	2.4+3.7	5.8	11.9	4.2	1.1	m
17	6.2	5.7	11.9	4.2	1.1	m
18	5.8	5.8	11.6	4.1	1.0	m
19	6.0	3.1+2.3	11.4	4.0	1.1	m
20	6.0	3.3+2.1	11.4	4.0	1.1	m
21	5.9	3.9	9.8	3.5	1.5	msm
22	5.8	3.8	9.6	3.4	1.5	msm
23	4.8	3.1	7.9	2.8	1.5	msm
24	4.8	3.1	7.9	2.8	1.5	msm